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REVISIONS AND CORRECTIONS

AREA Proceedings, Volume 40 (1939)

Changes in the text for the correction of typographical errors, and to take account of revisions, deletions and additions requested by committees in presenting their reports.

Page 79, 12th line under 11. Fire Insurance, should read "Company has the right to withhold the payment", etc.

Page 102, in formulas near middle of page, parentheses should embrace denominators as well as numerators.

Page 107, first formula, parentheses after first "equals" sign should embrace denominator as well as numerator.

Page 299, under Table B, change subheading "2. Railway Traffic" to "2. Highway Traffic".

Page 356, Conclusion (2). Change "1927" to "1937".

Page 373, second line under formula, "appearance of" should read "appearance or".

Page 374, last word in next to last paragraph should read "viaducts"; in next to last line "value" should be plural.

Page 428, fourth line, "surfaces" should be singular. Fifth line, third paragraph, "suction" should be "section".

Page 431, fourth paragraph, change last word in second line to "bending".

Page 432, change first word in second line to "Finsterwalder".

Pages 416, 418, 427, 428, last word at end of each appendix should be "discontinued".

Page 540, Appendix F. Change first sentence to read "The committee was able to find only one railroad company where asphalt was used in ballast", etc.

Page 581, revise subcommittee personnel as follows: H. R. Clarke, Chairman, Subcommittee; L. H. Bond, H. F. Fifield, J. DeN. Macomb, W. L. Roller, F. S. Schwinn, J. N. Todd, M. T. Zeeman.

Page 631, under Column Class "A", correct 26th line to "See Note "A". Under Column Class "B", correct 18th line to "Plan 1C—See Note "E".

Page 632, under Column Class "B", correct sixth line to "See Note "A".

Page 639, correct seventh line from bottom of page to "decrease of six inches in length", etc.

Page 548, Dimension and Plan No. 16, under "F" in second line of table, should be $6\frac{13}{16}$ in.

Page 563, the name of J. H. Kelly should be added to the personnel of the subcommittee under Appendix C.

PROCEEDINGS

OF THE

FORTIETH ANNUAL CONVENTION

OF THE

American Railway Engineering Association

HELD AT THE

PALMER HOUSE, CHICAGO, ILLINOIS
March 14, 15 and 16, 1939

VOLUME 40

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CHICAGO

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CONSTITUTION

Revised to June 1, 1938

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Standing and Special Committees.

(b) Meetings for discussion of reports and papers.

(c) The publication of papers, reports and discussions.

(d) The maintenance of a library.

4. Conclusions

The conclusions reached shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Illinois.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into four classes: Members, Life Members, Honorary Members and Associates.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class shall be not less than twenty-five (25) years of age.

(b) To be eligible for election to or retention of membership as a Member or an Associate, a person shall not be engaged directly and primarily in the sale to railways of appliances, supplies, patents or patented services.

B. MEMBER

A Member shall be:

(a) An Engineer or Officer in the service or on the retired list of a railway corporation who has had not less than five (5) years' of experience in the location, construction, operation or maintenance of railways.

Graduation in engineering from a school of recognized standing shall be considered as equivalent to three (3) years of active practice, and the satisfactory completion of each year of work in such school, without graduation, shall be considered as equivalent to one-half year of active practice.

(b) A Professor of Engineering in a university or college of recognized standing.

(c) An Engineer or Member of a public board or commission who in the discharge of his regular duties deals primarily with railway problems.

(d) An Engineering Editor of a magazine which deals primarily with railway matters.

C. Life Member

A Life Member shall be a Member who has paid dues for thirty-five (35) years, or who has been retired under a recognized retirement practice and has paid dues for not less than twenty-five (25) years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railway engineering or management.

(b) The number of Honorary Members shall be limited to ten (10).

E. Associate

An Associate shall be:

(a) An Engineer of a railway which is essentially an adjunct of an industry or which is used primarily to transport the products and materials of an industry to and from a railway which is a common carrier.

(b) A person qualified by training and experience to co-operate with Members in the object of this Association but who is not qualified to become a Member.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members and Life Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates shall have all the rights and privileges of the Association except those of voting and holding elective office.

Article III

Admission, Resignation, Expulsion and Reinstatement

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15th, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form prescribed by the Board of Direction.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of such Members shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(c) If an applicant is not personally known to three Members of this Association, the names of at least three well known persons engaged in railway or allied professional work to whom personally known shall be given instead. Each of such persons shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with all the information obtained, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible and the admission of the applicant shall be canvassed by letter ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (c) of this Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

A person elected to membership in this Association shall subscribe to its Constitution on the form prescribed by the Board of Direction. If this provision has not been complied with within six months of notice of election the election shall be considered null and void.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fully met.

7. Expulsion

Charges may be preferred in writing by ten or more Members against a person holding membership in the Association. The person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member or an Associate of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member or an Associate of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

An entrance fee of ten dollars ($10.00) shall be payable to the Association with each application for membership. This sum shall be returned to an applicant not elected.

2. Annual Dues

(a) The annual dues shall be ten dollars ($10.00)

(b) Life Members and Honorary Members shall be exempt from the payment of dues.

3. Arrears

A person whose dues are not paid before April 1st of the current year shall be notified by the Secretary. If the dues are still unpaid on July 1st further notice shall be given and a delinquent Member shall lose the right to vote. If the dues remain unpaid October 1st the person shall be notified on the form prescribed by the Board of Direction, and shall no longer receive the publications of the Association. If the dues are not paid by December 31st, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member or Associate who, for good reason is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice-Presidents, nine Directors, a Secretary and a Treasurer.

(b) The President, the Vice-Presidents and the Directors, together with the five latest living Past-Presidents continuing to be Members, shall constitute the Board of Direction, in which the government of the Association shall be vested, and shall act as Trustees and have the custody of all property belonging to the Association. The President, the Vice-Presidents and the Directors shall be Members.

(c) The Secretary and the Treasurer shall be appointed by the Board of Direction.

2. Term of Office

The term of office of the President shall be one year, of the Vice-Presidents two years and of the Directors three years. The term of each shall begin at the close of the Annual Convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position during the pleasure of the Board of Direction.

3. Officers Elected Annually

(a) There shall be elected at each Annual Convention a President, one Vice-President and three Directors.

(b) The candidates for President and for Vice-President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election. Vice-Presidents and Directors shall not be eligible for re-election to the same office until at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) When a vacancy occurs in the office of President the duties shall be performed by the senior Vice-President.

(b) When a vacancy occurs in the office of either Vice-President the Board of Direction shall select a Vice-President from among the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) A vacancy in the office of Director shall be filled by the Board of Direction.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provisions of Article V, Section 4.

6. Vacation of Office

(a) When an elected officer ceases to be a Member of the Association, as provided in Article II, the office shall be vacated.

(b) In case of the disability of or neglect in the performance of duty by an officer, the Board of Direction, by a two-thirds affirmative vote of the entire Board, shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not officers shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past-President who is a member of the Committee shall be the Chairman of the Committee. In the absence of the senior Past-President from a meeting of the Committee the Past-President next in seniority present shall act as Chairman.

2. Method of Nominating

(a) Prior to December 1st of each year the Chairman shall call a meeting of the Committee at a convenient place, at which nominees for the various elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee.*	*Number of Candidates to be elected at the Annual Election of Officers.*
President	1	1
Vice-President	1	1
Directors	9	3
Nominating Committee	10	5

(b) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

(c) At any time between January 1st and February 1st any ten or more Members may send to the Secretary additional nominations for any elective office for the ensuing year signed by such Members.

(d) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, the name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each Annual Convention, the Secretary shall issue a ballot to each voting member of record in good standing, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate, his record of membership and activities in this Association.

4. Substitution of Names

Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names

voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw a ballot, and cast another, at any time before the polls close.

(c) Ballots not endorsed or from persons not qualified to vote shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by tellers appointed by the Presiding Officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

(c) The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio a member of all committees, except the Nominating Committee.

2. Vice-Presidents

The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and shall discharge the duties in case of a vacancy in the office.

3. Treasurer

The Treasurer shall receive all monies, deposit the same in the name of the Association, receipt to the Secretary therefor and invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. The Treasurer shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

4. Secretary

The Secretary, shall be under the direction of the President and Board of Direction, the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. The Secretary shall see that the monies due the Association are collected and without loss transferred to the custody of the Treasurer, and shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. The Secretary is to conduct the correspondence of the Association, keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

5. Auditing of Accounts

The accounts of the Treasurer and of the Secretary shall be audited annually by an approved accountant under the direction of the Finance Committee of the Board of Direction.

6. Board of Direction

(a) The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

(b) The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(c) Seven members of the Board of Direction shall constitute a quorum.

(d) At the first meeting of the Board of Direction after the Annual Convention, the following committees, each consisting of not less than three members, shall be appointed by the President from the Board of Direction and they shall report to and perform their duties under the supervision of the Board of Direction.

Finance
Publication
Library
Outline of Work of Committees
Personnel of Committees
Membership
Manual

7. Duties of the Committees of the Board of Direction

(a) Finance Committee

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of monies and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(b) Publication Committee

The Publication Committee shall have general supervision of the publications of the Association. The Publication Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(c) Library Committee

The Library Committee shall have general supervision of the Library and the property therein, shall make recommendations to the Board of Direction with reference thereto, and shall direct the expenditures for books and other articles of permanent value, from such sums as may be appropriated for these purposes.

(d) Committee on Outline of Work of Committees

The Committee on Outline of Work of Committees shall prepare and present to the Board of Direction a report of the subjects to be investigated, considered and reported upon by the standing and special committees of the Association during the ensuing year.

(e) Committee on Personnel of Committees

The Committee on Personnel of Committees shall prepare and present to the Board of Direction a list of chairman, vice-chairmen and members of the standing and special committees of the Association for the ensuing year.

(f) Membership Committee

The Membership Committee shall make investigation of applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(g) Manual Committee

The Manual Committee shall study and recommend to the Board of Direction as to the manner in which the material adopted for addition or deletion from the Manual shall be handled.

8. Standing Committees

The Board of Direction may appoint standing committees to investigate, consider and report upon questions pertaining to railway location, construction, operation and maintenance.

9. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

10. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

11. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Illinois. The convention shall open on a Tuesday in the month of March to be determined by the President.

(b) The Secretary shall notify all members of the Association of the time and place of the Annual Convention at least thirty (30) days in advance thereof.

(c) The order of business at the Annual Convention of the Association shall be:

Reading of the Minutes of the last meeting
Address of the President
Reports of the Secretary and the Treasurer
Reports of Committees
Unfinished Business
New Business
Installation of Officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to members and to those others invited by the Presiding Officer to speak.

2. Special Meetings

Special meetings of the Association may be called by the Board of Direction and special meetings shall be so called by the Board of Direction upon written request of thirty Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten (10) days in advance and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five (25) Members shall constitute a quorum at all meetings of the Association.

Article IX

Amendment

1. Amendment

Proposed Amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members and shall be acted upon in the following manner:

The amendment shall be presented to the Secretary, who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes the matter shall be submitted to the Association by letter-ballot.

The Board of Direction shall canvass the ballots which have been received within sixty days after the date of issue of the letter-ballot and if two-thirds (⅔) of the votes so received are in the affirmative the amendment shall be declared adopted and shall become immediately effective.

The result shall be announced at the next Annual Convention.

GENERAL INFORMATION

(Subject to change from time to time by Board of Direction)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS

(A) Appointment of Committees and Outline of Work

Standing Committees

1. *The following are Standing Committees:

I. Roadway and Ballast.
III. Ties.
IV. Rail.
V. Track.
VI. Buildings.
VII. Wood Bridges and Trestles.
VIII. Masonry.
IX. Highways.
X. Signals and Interlocking.
XI. Records and Accounts.
XII. Rules and Organization.
XIII. Water Service, Fire Protection and Sanitation.
XIV. Yards and Terminals.
XV. Iron and Steel Structures.
XVI. Economics of Railway Location and Operation.
XVII. Wood Preservation.
XVIII. Electricity.
XX. Uniform General Contract Forms.
XXII. Economics of Railway Labor.
XXV. Waterways and Harbors.
XXVI. Standardization.
XXVII. Maintenance of Way Work Equipment.

Special Committees

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Section 9, of the Constitution.

The following are Special Committees:

Stresses in Railroad Track.
Clearances.
Waterproofing of Railway Structures.
Economics of Bridges and Trestles.
Complete Roadway and Track Structure.
Impact.

Personnel of Committees

3. The personnel of all committees will continue from year to year, except when changes are announced by the Board of Direction. Ten percent of the membership of each committee shall be changed each year.

Members of committees who do not attend meetings of committees during the year or render service by correspondence will be relieved and the vacancies filled by the Board at the succeeding annual convention.

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* By action of the Board of Direction on December 8, 1937, Committee II—Ballast was consolidated with Committee I—Roadway; Committee XXI—Economics of Railway Operation was consolidated with Committee XVI—Economics of Railway Location, and Committee XXIII—Shops and Locomotive Terminals was abolished.

Outline of Work

4. As soon as practicable after January 1st of each year the Board of Direction will assign to each committee the subjects which, in its judgment, should preferably be considered during the current year. Committees are privileged to present the results of any special study or investigation they may be engaged upon or that may be considered of sufficient importance to warrant presentation.

(B) Preparation of Committee Reports

General

5. The collection and compilation of data and subsequent analysis in the form of arguments and criticism is a necessary and valuable preliminary element of committee-work.

Collection of Data

6. Committees are privileged to obtain data or information in any proper way. If desired, the secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

Plan of Reports

7. Committee reports should be prepared as far as practicable to conform to the following general plan:

(a) It is extremely important that every committee should examine its own subject-matter in the Manual prior to each annual convention, and revise and supplement it, if deemed desirable, giving the necessary notice of any recommended changes in accordance with Section 6 (a) of the General Rules for the Publication of the Manual. If no changes are recommended, statement should be made accordingly.

(b) When deemed necessary, the previous report should be reviewed.

(c) Subjects presented in previous reports on which no action was taken should be resubmitted, stating concisely the action desired. It may not be necessary to repeat the original text in the report, reference to former publication being sufficient, unless changes in the previously published version are extensive. Minor changes can be explained in the text of the report.

Definitions

(d) Technical terms used in the report, the meaning of which is not clearly established, should be defined, but defined only from a technical standpoint. Ordinary terms, universally understood, need not be defined.

History

(e) If necessary, a brief history of the subject-matter under discussion, with an outline of its origin and development, should be given.

Analysis

(f) An analysis of the most important elements of the subject-matter should be given.

Argument

(g) The disadvantages of the present practices and the advantages of the recommended practices should be set forth.

Illustrations

(h) Illustrations accompanying reports should be prepared so that they can be reproduced on one page. The use of inserts should be avoided as much as possible, on account of the increased expense and inconvenience in referring to them. Plans showing current practice, or necessary for illustration are admissible, but those showing proposed definite design or practice should be excluded. Recommendations should be confined to governing principles.

Conclusions

(i) The conclusions of the committee which are recommended for publication in the Manual should be stated in concise language, logical sequence, and grouped together, setting forth the principles, specifications, definitions, forms, tables and formulas included in the recommendation. Portions of the text of the report which are essential to a clear interpretation and understanding of the conclusions, should be included as an integral part thereof.

(C) Publication of Committee Reports

Reports Required

8. (a) Reports will be required from each of the standing and special committees each year.

(b) Although several subjects may be assigned to each committee by the Board of Direction, a full report on only one subject is expected at each annual convention, but the preliminary work on some of the remaining subjects should be in progress, and, when deemed advisable, partial reports of progress should also be presented. This method allows time for their proper preparation and consideration.

Date of Filing Reports

9. Committee reports to come before the succeeding convention for discussion should be filed with the secretary on or before the dates specified in the schedule prepared by the publication committee, copies of which will be furnished the committee chairman.

10. Committees engaged upon subjects involving an extended investigation and study are privileged to present progress reports, giving a brief statement of the work accomplished, and, if deemed expedient, a forecast of the final report to be presented.

Publication of Reports

11. Committee reports will be published in the bulletin in such sequence as the Board of Direction may determine, for consideration at the succeeding convention. Reports will be published in the form presented by the respective committees. Alterations ordered by the convention will be printed as an appendix to the report.

Written Discussions

12. Committees should endeavor to secure written discussions of published reports. Written discussions will be transmitted to the respective committees, and if deemed desirable by the committee, the discussions will be published prior to the convention and be considered in connection with the report.

Verbal Discussions

13. Each speaker's remarks will be submitted to him in writing before publication in the proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(D) Consideration of Committee Reports

Sequence

14. The sequence in which committee reports will be considered by the convention will be determined by the Board of Direction.

Method

15. The method of consideration of committee reports will be one of the following:

(a) Reading by title.
(b) Reading, discussing and acting upon each conclusion separately.
(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

Final Action

16. Action by the convention on committee reports will be one of the following, after discussion is closed:

(a) Receiving as information.
(b) Receiving as a progress report.
(c) Adoption of a part complete in itself and referring remainder back to committee.
(d) Adoption as a whole.
(e) Recommittal with or without instructions.
(f) Adoption as a whole.
(g) Recommendation to publish in the Manual.

Note.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the committee considers affected.

The Chair will decline to entertain amendments which in his opinion lie entirely within the duties of the editor.

(E) Publication of Abstracts by Technical Journals

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the Bulletin; provided, application therefor is made in writing and proper credit be given the Association, authors or committees presenting such material.

PROCEEDINGS

The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction and maintenance of railways.
Its action is not binding upon its members.

TUESDAY, MARCH 14, 1939

MORNING SESSION

The fortieth annual convention of the American Railway Engineering Association was called to order in the Grand Ball Room of the Palmer House, Chicago, Ill., by the President, Mr. F. E. Morrow, Chief Engineer, Chicago & Western Indiana Railroad and Belt Railway of Chicago.

President Morrow: Will the Board of Direction please come to the platform? We are now opening our Fortieth Annual Convention. The first order of business is the matter of the approval of the minutes of the last convention. They have been published in the Proceedings and have been in your hands for some time. If there is no objection, I will declare them approved as published. The next order of business is the president's address.

ADDRESS OF PRESIDENT F. E. MORROW

The order of business as prescribed by the constitution of the Association provides that there shall be an address by the president at this time. It seems to me that the Association, in definitely prescribing this order of business, must have been willing to assume great risks and prepared to absorb a large amount of punishment. There is no subject assigned, but I presume that it was the intent that such an address should be devoted to a review of the affairs of the Association.

Financial Affairs in Excellent Condition

From the reports of the Secretary and Treasurer, which will be presented later, it will be observed that the financial affairs of the Association are in excellent condition. For the past several years there has been some excess of ordinary receipts over ordinary disbursements. In the years 1935 to 1938, approximately $15,000 was spent on editing and publishing the new Manual in excess of receipts from the sale of the Manual, and this excess was drawn from surplus. However, in spite of this extraordinary expenditure our surplus remains in excess of $80,000, which is adequate for our needs. There was a slight loss in membership during the year, but the total of our membership varies to a considerable degree with general economic conditions. For example, during the depth of the depression, in the period from 1930 to 1935, we had substantial losses in our membership. Since that time there have been some losses and some gains, but on the whole the membership has continued approximately the same since those losses. While it is true that the employment of engineers by the railroads has been substantially reduced in the last 10 years, it seems reasonable to suppose that there are many engineering employees who are not now members of our Association who could with profit to themselves and their employers become members of the Association, and your Board is considering ways and means of inducing such men to join us.

Your Board is giving consideration to the possibility of a change in the time of our annual convention. This consideration is being given from the standpoint of perhaps finding a more acceptable time for the members to attend our convention, and the possibility

of arranging a time in co-operation with other associations and other sections of the Engineering division, and the National Railway Appliances Association, which would be a benefit to all of these activities. Any change in the time of our convention will require an amendment to our constitution and it is quite possible that this matter may be presented to you during the coming year.

During the past year it has been the endeavor of your officers to conduct all of the essential activities with the minimum expenditure of time and expense on account of the depressed economic conditions. As a matter of fact, the very first job that your president had upon assuming office was to devise ways and means of reducing the budgets of the Engineering division approximately 10 percent. This was done without the sacrifice of a great deal of the essential activities but it did eliminate the consideration of any new and larger activities. On the whole, I feel that we have been able to carry on our most essential activities in a satisfactory manner.

Objectives of the Association

Our activities are directed towards the accomplishment of two objectives:

1. The collection and dissemination of information designed to improve materials and methods in the construction and maintenance of our railroads.

2. To aid in the development of the individual members of the engineering staffs of our railroads.

Constant change takes place through the discovery and improvement of available materials. Manufacturers are constantly striving to provide new and better machines, tools and equipment, and the engineering staffs of the railroads are constantly on the alert to improve their methods. One of our major activities is the constant survey of these fields of activity in order to keep our membership abreast of these developments. Our committees are maintained for this purpose. It is their function to study and report on them, and then separate the wheat from the chaff and formulate our recommended practices. These first appear in our bulletins, later after they have been presented to the convention they appear in our proceedings, and recommended practices that are adopted by the convention then appear in our Manual.

Another important activity is the carrying on of certain original research work which is authorized and financed by the Association of American Railroads. In some instances these projects are financed entirely by the Association and in other cases they are in part financed by the Association and in part by manufacturers and other industrial interests. These activities have resulted in important discoveries and improvements in practices. It is our expectation that others which are in process will likewise result in important improvements. There are many other fields available for profitable exploration through research projects and it is our hope and expectation that these will be carried on just as fast as funds are available for them.

Importance of Committee Work

This is all very important work and one in which the railroads are vitally concerned. I would like to impress upon the members of our committees the importance of the work which they are called upon to perform and to implant in their minds a feeling of greater responsibility in connection with the development of data in connection with their reports, their findings and in the language in which these matters are reported. I think if each committee member could always visualize the great importance of his work that he would necessarily feel greater responsibility and would endeavor to make his work as near perfect as is practicable. Our reports and recommendations are dissemi-

nated among engineers throughout the world and the products of our labor are considered standard among all railroad men. Therefore, it behooves us to exercise the utmost care in the formulation of our reports and the conclusions thereon. I would also like to impress upon our members that it is the quality of the reports which is important and not the volume. It is of course important that new developments be made available to the engineers of our railroads as soon as practicable, but at the same time they should be made available in such a way as not to mislead anyone.

I realize that the successful conduct of committee work has become more difficult in the last few years because the engineering staffs of the railroads have been reduced in adjustment to changed economic conditions, and the desirable amount of time which can be devoted to committee work is many times seriously curtailed. In spite of these added difficulties the high standard of our committee reports has been maintained and it is gratifying that this is true. It should be realized that we are engaged in one of the essential activities of railroading and that such work should not be curtailed in any of its essentials.

Value to the Young Engineer

The second important objective is by no means the lesser of our objectives. I do not know of any activity which serves to develop engineers, and the young engineers especially, as the contacts with other engineers engaged in the same line of work which take place in our committee work and in the work of preparing reports. This work enlarges the horizon of each individual engineer and acquaints him with many ideas and practices which would not be available to him when engaged solely in his own individual work on his own railroad. These contacts are invaluable in the development and growth of the individual engineer. I know from my own experience that work in this Association has been invaluable to me and that it has resulted in a great improvement of my work with my own company. It is my sincere hope that this phase of our work will be fully appreciated by the individuals of the railroad staffs and by the officers of the railroads who have the authority to permit or curtail such activities on the part of their employees.

The last few years have been difficult ones both for the railroads and railroad employees. These difficulties are not limited to the railroads but are greatly emphasized in that industry. These difficulties are still with us and we cannot yet see the outcome. However, the railroads are a vital and essential industry and their successful operation is an important factor in the welfare of the nations which they serve. While awaiting the successful solution of these problems it is our task to perform each duty to the very best of our ability, sustained and supported by unswerving faith that these problems will ultimately be solved in a satisfactory manner.

In closing I wish to express my sincere appreciation of the very loyal support and co-operation of all of our officers and staff, committee members, associates in the Engineering division, and the officers and staff of the Association of American Railroads.

President Morrow: The next order on our program is an address by Mr. King, vice-president of the Association of American Railroads. Mr. King has only recently assumed this position. He is a railroader and he knows the problems of railroading. It is with a great deal of pleasure that I introduce to you at this time, Mr. King. (Applause).

ADDRESS OF J. W. KING

Vice-President Operations and Maintenance Department, Association of American Railroads, Washington, D. C.

I can assure you that it is a real pleasure to be here today as it gives me an opportunity not only to listen to your proceedings but to become acquainted with so many fellow railroad workers of your particular profession whom I have not known before but hope to know better in the future. I am particularly happy to be here on this occasion for the reason that a fellow Virginian, I understand, will be elected your president in the ensuing year. There was some discussion about that last night. I don't know whether he will get the required number of votes or not. (Laughter). When Mr. Morrow invited me to talk to you on this occasion, I rather hesitated to do so upon three grounds; first, I had never been a speaker but just an ordinary hard-working transportation man; second, it would be my initial attempt after being with the Association only one and one-half months, and, third, not an engineer myself I knew I would have to appear before a group of technical men where one is likely to be closely analyzed and checked. But having been a member of your Association for about six years and this being my first opportunity to attend one of your meetings, I felt I should undertake the task and attempt to say something to you.

It is needless for me to say that your Association enjoys an enviable reputation. In the forty years of its organization its achievements in advancing the science and art of railway engineering have been of two-fold benefit. They have aided greatly in the education of two full generations of young engineers who have entered railway service during that time, and they have been responsible for valuable improvements in construction and maintenance practices.

Identification With A A R

Unquestionably, the usefulness of the AREA to the railroads has been materially enhanced as a result of its identification with the Association of American Railroads as the Construction and Maintenance Section of the Engineering Division, because through this relationship recommended practices of the AREA have become recommended practices of the AAR. This increased prestige carries with it increased responsibility. However, the primary function of the AAR, in its relation to the AREA, is to effect a co-ordination of its work with that of the other divisions and sections, to insure that they are all working to a common end—the progressive improvement of the railroads as a transportation Agency. The AAR also serves as the means of bringing to the attention of your committees problems which, in the opinion of the railway managements, are currently of most vital concern. Further than this, it has enabled the AREA to function as a clearing house through which engineering officers have been appointed on special AAR committees to represent the railroads at public hearings, in negotiations with public authorities, and to deal with matters requiring close contact with other divisions and sections of the AAR.

The value of your Association to the AAR is attested by the fact that the AAR has appropriated for expenditure in 1939 a total of $80,600 to cover allotments for various research projects of the Engineering Division, including its share of the operating expenses of the Construction and Maintenance Section.

Possible Improvement in Methods

In spite of your record of achievement and the reputation your Association has so justly earned, I would like to offer a few thoughts for your consideration, and they apply with equal force to any railroad organization today. Are you giving attention to

the problems of greatest concern to the railroads? Are you attacking them with a thorough understanding of just what is needed? Are the results of your studies presented in a form that will make them most useful to the men who have the most urgent need for the information you have developed and the conclusions at which you have arrived? Are your investigations made and conclusions reached without unnecessary delay? I do not wish to infer in the least that you are not doing a practicable job, and doing it promptly. It is merely my thought to direct attention to the fact that because your methods and policies have proven so highly effective over a period of forty years they may still not represent the best that can be devised with the fine talent at your command to meet present day conditions. We all must realize that the present conditions facing the railroads are extremely critical. Possible improvements in methods will not become apparent unless one is constantly on the lookout for them.

It is recognized, of course, that the work of the engineer, particularly when it involves the solution of some complex problem, cannot be conducted as rapidly as the work of the transportation officer, who must make spot decisions on the basis of the information available and with a background of previous experience with comparable situations. The planning of engineering projects or the development of sound engineering practices is necessarily a time-consuming process, and this is especially true of the work involved in the gathering and correlating of experiences, test data and opinions necessary for the preparation of authoritative reports by your various committees.

However, in spite of the serious obstacles that stand in the way of the expeditious completion of your assignments, I wish to suggest that you keep in mind at all times the importance of making the results of your labors available as soon as possible. There has never been a time in the history of the railroads before when it was so important to apply as promptly as practicable any development that will be fruitful of economy in railway transportation, or which will be productive of better results for the same money.

The Manual

Probably the most tangible evidence of accomplishment on the part of the American Railway Engineering Association is its Manual of Recommended Practices. This volume of 1,600 pages presents an impressive appearance even to someone who could not be expected to have an appreciation of its contents. It represents unselfish and conscientious labors of many men over many years. Now that it is published in looseleaf form, the annual supplements of revision sheets afford a comprehensive measure of the steps that are being taken to keep it up-to-date by adding new material and amending matter already included in it.

The fact that the Manual has assumed such large proportions lends interest to your policy of maintaining close co-operation with other engineering associations, with a view to the adoption of specifications and standards of others by title, where this seems advisable. This practice appears to be in the interest of economy and is in line with the policy of the AAR regarding the development of common standards, as evidenced in its financial contributions to the American Standards Association.

I am told the questions raised most frequently concerning the Manual do not relate to the technical merits of its contents, but to the fact that its contents are not more generally adopted by the railroads. Possibly the most valid explanation for this is to be found in the title—that of "Recommended Practices", rather than mandatory standards. It is realized, of course, that the value of the Manual is not to be measured solely by the extent to which the specifications, plans, rules, etc., have been adopted in their entirety by the various railways, because of the wide use being made of them

as models or guides in the drafting of similar but somewhat modified instruments for the same purpose.

Possibly, you already have the answer. If not, may I suggest that you give some consideration to it?

In conclusion, let me add that the engineering profession generally,—civil, mechanical and all other kinds,—has done much over the years toward improving railroad plants that transportation of goods and passengers could be expedited and thus give to the American public better service. This applies especially to such work as the straightening of curves, reduction of grades, making stronger structures, eliminating highway crossings, improving track maintenance, perfecting improved signaling systems and, very importantly, the development of better locomotives and equipment of all types.

The Results Obtained

As a result of these and other improvements, passenger trains are now operating at speeds up to 100 and more miles per hour; freight trains up to 60 miles per hour. Passengers are nearer as between the important centers of population by one, two, three or more days, depending upon distance, than a few years ago. The fruit grower in California is three days nearer the eastern seaboard markets than formerly; two days nearer the Chicago market and correspondingly nearer other consuming points. The citrus fruit grower in Florida is two days nearer the heavy consuming areas in the North and Middle West. The fruit and vegetable growers in Georgia and the Carolinas are one to two days closer to the eastern seaboard markets. Freight service between Chicago, St. Louis and New York, has been quickened two days; between St. Louis and Texas two days; between Chicago and New Orleans two days. These are merely typical; numerous other instances of improved service could be cited. Many over-night freight runs for distances from 300 to 500 miles in all parts of the country are being made as compared with two to three days for the same distances a few years ago.

Anyone will have to admit these are remarkable achievements, but with the extremely critical condition of the railroads today, faced as they are with all kinds of unfair and subsidized competition, we cannot rest on our laurels but must go forward in every endeavor for constant improvement in the railroad plants. I am very sure your Association and its members individually can be depended upon to continue to do their part. I thank you. (Applause).

President Morrow: Mr. King, I want to thank you for being here and for giving us the benefit of your address. We will now have the reports of the secretary and the treasurer.

(W. S. Lacher, the secretary, then offered some brief comments on the reports of the secretary and the treasurer, which appear on pages 36 to 45, inclusive.)

President Morrow: You have heard the reports of the secretary and the treasurer. What is your pleasure?

(Upon motion regularly seconded, the reports of the secretary and treasurer were accepted.)

President Morrow: I have here an expression of greetings and best wishes for a successful meeting from E. H. Fritch, who is prevented from attending on account of illness. I also have a message from Mr. Forsberg, Chief Engineer of the Pittsburgh & Lake Erie, who says he cannot be here, and this is the first convention he has missed since he has been a member.

We expected to have with us at this convention, Mr. MacDonald, Chief of the Bureau of Public Roads, but on account of illness he is not able to be here. He has sent me a radiogram which I will read to the convention:

"Regret exceedingly that I am unable to be present to confer with your Association. I have been looking forward to this meeting with a feeling that it would be full of mutual interest and profit as was the preceding one. The committee representing the railroads on the grade crossing activities, of which Mr. R. E. Dougherty is chairman and Mr. John Brennan, executive engineer, has provided a satisfactory means for the development of policies and the smoothing of difficulties. During the current year we hope, in co-operation with the committee, to submit a plan of classification for grade crossings that will simplify programming and assure the direction of funds where most urgently needed. To make such a plan effective will require co-operation of the state highway departments, the railroad engineers and executives and the Bureau. From our past experience, I feel confident such co-operation is already assured. Will you express the appreciation of the Bureau of Public Roads for the co-operation which we have had from the Committee on Railroad Grade Crossings and the railroad engineers in carrying forward the grade crossing elimination program?

THOMAS H. MACDONALD,
Chief of the Bureau of Public Roads".

Reports of committees were presented in the following order:

26—Standardization
(For Report, see pp. 65–69. For Discussion, see p. 720.)

18—Electricity
(For Report, see pp. 71–74. For Discussion, see p. 772.)

Special—Clearances
(For Report, see pp. 75–76. For Discussion, see p. 719.)

20—Uniform General Contract Forms
(For Report, see pp. 77–81. For Discussion, see p. 725.)

16—Economics of Railway Location and Operation
(For Report, see pp. 83–181. For Discussion, see p. 773.)

The session recessed at 1:00 p.m.

AFTERNOON SESSION

The session convened at 2:00 p.m., Vice-President Fanning presiding.

Reports of committees were presented in the following order:

25—Waterways and Harbors
(For Report, see pp. 285–290. For Discussion, see p. 743.)

27—Maintenance of Way Work Equipment
(For Report, see pp. 305–331. For Discussion, see p. 756.)

13—Water Service, Fire Protection and Sanitation
(For Report, see pp. 219–247. For Discussion, see p. 732.)

Address by C. E. Smith on "The New England Hurricane."
(See pp. 46–58.)

The session recessed at 4:05 p.m.

WEDNESDAY, MARCH 15, 1939

MORNING SESSION

The session convened at 9:00 a.m., President Morrow presiding.

Reports of committees were presented in the following order:

9—Highways
(For Report, see pp. 291–303. For Discussion, see p. 726.)

10—Signals and Interlocking
(For Report, see pp. 183–186. For Discussion, see p. 721.)

22—Economics of Railway Labor
(For Report, see pp. 333–360. For Discussion, see p. 750.)

5—Track
(For Report, see pp. 543–592. For Discussion, see p. 760.)

Special—Complete Roadway and Track Structure
(For Report, see pp. 627–633. For Discussion, see p. 791.)

President Morrow: I wish to appoint the following as tellers for canvassing the vote:

R. C. Bardwell, *Chairman*
S. H. Poore,
R. A. Morrison
J. N. Todd
A. B. Pierce
R. M. Stimmel
H. E. Kirby
J. B. Wesley
C. H. R. Howe
H. E. Silcox
O. E. Mace
D. C. Teal
H. F. King
A. R. Wilson

This committee is requested to meet in Room 11 at two p. m., or just following the luncheon.

The meeting recessed at eleven forty-five o'clock.

AFTERNOON SESSION

The session convened at 2:30 p.m., Vice-President Fanning presiding.

Reports of committees were presented in the following order:

1—Roadway and Ballast
(For Report, see pp. 519–542. For Discussion, see p. 729.)

4—Rail
(For Report, see pp. 593–624. For Discussion, see p. 738.)

Special—Stresses in Railroad Track
(For Report, see pp. 625–626; 641–654.)

Secretary Lacher: Mr. President, the report of the tellers reads as follows:

"We, the Committee of Tellers, report the following as the result of the count of the ballots:

For President:
E. M. Hastings

For Vice-President (to serve two years):
F. L. C. Bond

I will say in explanation right there that Mr. Fanning will continue to serve his second year as Vice-President.

For Directors (three to be elected):

Robert Faries.....483 votes
G. R. Smiley.....443 votes
J. B. Akers.....376 votes
R. C. Gowdy.....346 votes
C. E. Smith.....301 votes
F. W. Alexander.....293 votes
C. P. Richardson.....203 votes
H. Austill.....184 votes
F. P. Turner.....184 votes

For Members of the Nominating Committee (five to be elected):

H. M. Church.....622 votes
E. T. Howson.....612 votes
Geo. F. Hand.....571 votes
G. H. Trout.....565 votes
W. B. Irwin.....428 votes"
J. A. Lahmer.....427 votes
J. F. Pringle.....418 votes
M. J. J. Harrison.....408 votes
R. C. White.....352 votes
A. C. Shields.....179 votes

Respectfully submitted,

R. C. Bardwell,
Chairman.

Following this, the report of Committee 3—Ties, was presented.

(For Report, see pp. 635–640. For Discussion, see p. 786.)

The session recessed at 5:55 p.m.

THURSDAY, MARCH 16, 1939

MORNING SESSION

The session convened at 9:05 a.m., President Morrow presiding.

Reports of committees were presented in the following order:

17—Wood Preservation
(For Report, see pp. 457–517. For Discussion, see p. 723.)

6—Buildings
(For Report, see pp. 187–218. For Discussion, see p. 795.)

14—Yards and Terminals
(For Report, see pp. 249–283. For Discussion, see p. 735.)

11—Records and Accounts
(For Report, see pp. 435–456. For Discussion, see p. 744.)

Special—Waterproofing of Railway Structures
(For Report, see p. 361. For Discussion, see p. 749.)

15—Iron and Steel Structures
(For Report, see pp. 363–371. For Discussion, see p. 794.)

The session recessed at 11:00 a.m.

AFTERNOON SESSION

The session convened at 2:00 p.m., Vice-President Hastings presiding.

Reports of committees were presented in the following order:

8—Masonry
(For Report, see pp. 401–433. For Discussion, see p. 764.)

Special—Economics of Bridges and Trestles
(For Report, see pp. 372–374. For Discussion, see p. 747.)

7—Wood Bridges and Trestles
(For Report, see pp. 375–399. For Discussion, see p. 789.)

Special—Impact
(For Report, see p. 362. For Discussion, see p. 732.)

Mr. A. R. Wilson (Pennsylvania): May I have the privilege of coming to the platform?

President Morrow: You may have that privilege.

Mr. Wilson: President Morrow—better known to many as Fred Morrow: Today you are concluding your administration as president of the American Railway Engineering Association. You have served in many positions well with keen insight, deliberate decisions and a friendly attitude. Those of us who have served in official positions with you have learned more intimately of your fine character and ability.

You have other qualifications than engineering and administration. As I understand, it is unwise to challenge you in a game of pushing the pill around the green. All of these merit the esteem and high regard your fellowmen have for you.

Mr. Morrow, it is my privilege and pleasure, on behalf of this Association, to present to you a plaque, which in meager terms, signifies the appreciation we have of your services. It reads:

"The American Railway Engineering Association presents this tablet to Frederick E. Morrow, President 1938–1939 in grateful appreciation of his valuable service. His zealous efforts, able leadership and mature judgment were of untold value in advancing the usefulness of the Association to the railroads."

President Morrow: Mr. Wilson, Members of the Association: These are kind and comforting words, and I trust that, in some measure, I may have measured up to them.

It has been a great pleasure to me to serve the Association, because of the many fine contacts and friendships which have developed in that work. I want to express my very sincere appreciation of the whole-hearted and superb cooperation which I have received from all of the members and all of the officers and the staff of this Association.

This year will always remain in my memory as one of the high spots of my brief sojourn in this world and, while I am giving up this position with something of relief, I will carry from this position many happy memories.

I thank you. (Applause).

Is there any other new business?

Mr. H. E. Kirby (Chesapeake & Ohio): I would like to offer a resolution.

"Be it resolved, That the American Railway Engineering Association, in convention assembled, records its appreciation to C. E. Johnston for his constructive and challenging address at our luncheon, which address emphasized to our members the

acuteness and the unfairness of the competition that has grown up on the highways and stimulated action among our members individually in combating this trend."

(The motion was seconded, put to a vote and carried.)

Mr. W. G. Nusz (Illinois Central): *"Be it resolved,* That the American Railway Engineering Association, in convention assembled, thanks C. E. Smith for his illuminating and dramatic description of the hurricane and floods that struck the railways of New England with such force last September, and for his portrayal of the aggressive rehabilitation measures adopted by the New York, New Haven & Hartford and the Boston & Maine in meeting the emergency created by this disaster."

(The motion was seconded, put to a vote and carried.)

Mr. W. T. Dorrance (New York, New Haven & Hartford): Mr. Morrow, I would like to offer a resolution:

"Be it resolved, That the American Railway Engineering Association, in convention assembled, extends its appreciation to the National Railway Appliances Association for the constructive exhibit of materials and equipment applicable to the construction and maintenance of railway roadway and structures, presented concurrently with this convention, which exhibit has added much to the educational value of our meeting."

I move its adoption.

(The motion was seconded, put to a vote and carried.)

Mr. C. C. Haire (Illinois Central): I move the adoption of the following resolution:

"Be it resolved, That the American Railway Engineering Association, in convention assembled, expresses thanks to J. W. King for his friendly, encouraging message at the opening session of our convention and for his commendation of the work of our Association in the forty years of its activities."

(The motion was seconded, put to a vote and carried.)

Mr. C. J. Geyer (Chesapeake & Ohio): Mr. President, I move the adoption of the following resolution:

"Be it resolved, That the American Railway Engineering Association, in convention assembled, expresses its appreciation to the Western Railway Club for the privilege of joining in the meeting on Wednesday evening, at which Messrs. H. R. Clarke and K. Cartwright brought to us information of such direct interest to us on one of the most pressing problems confronting our members today. We feel that this program was of unusual interest and we are happy to have participated in it."

(The motion was seconded, put to a vote and carried.)

President Morrow: Is there any other business? If not, we will proceed to the next order of business. We have had an election and have elected some new officers. As I call out the names of the elected Directors, I would like to have them rise.

Robert Faries. I do not believe Mr. Faries is here. I think I heard him say he would have to return east last night.

Mr. G. R. Smiley. (Applause) Mr. J. B. Akers. (Applause)

We also elected a vice-president to serve two years, Mr. F. L. C. Bond. (Applause).

I will now ask Mr. J. C. Irwin and Mr. Hadley Baldwin to escort the new president-elect to the rostrum.

(President-Elect Hastings was escorted to the rostrum.) (Applause)

President Morrow: Mr. Eddie Hastings. Some twenty-odd years ago I met Mr. Hastings when we were both members of the Committee on Yards and Terminals. Little did I visualize that twenty years later he and I would find ourselves in this position. During those twenty years we have had many contacts in our various

duties in the Association. From those contacts a very lasting friendship has developed, and I have learned to love Mr. Hastings and to value his judgment and to respect his ability.

It affords me a great privilege to be in this position and to pass on from my hands to his the leadership of this organization for the next year. In doing so I realize that I am passing to him a great responsibility, a great opportunity for important work, and I know that, in doing so, I express the trust and the appreciation of the Association that he will perform the duties of this office in a superb manner.

In token of your election to the office of President, I present you with this gavel which I hope and trust you will use to rule over this Association in a high and commendable manner. (Applause)

(President Hastings assumed the chair.)

President Hastings: There is not very much that a man can say when he finds himself in the position that I find myself in this afternoon.

It is a peculiar joy to receive this from the hands of my friend, Fred Morrow, for, as he has said, we have had quite a number of years together, and I know that neither one of us ever expected that we would occupy our respective positions today.

I feel very humble in the honor that you have conferred upon me. I cannot feel that I deserve it but you must have because you have put me here. I only trust that I can faithfully and completely fulfill the things which you expect of me. I shall do it if I have the support that you have always given to your executive, and have the feeling always that each one of you stands behind the officers of your Association.

We are confronted today with many things that disturb the minds of men. Since I have been in Chicago I have not had the time to read carefully the daily press, but that portion that I have found the time to read disturbs you to the very innermost recesses of your mind. We do not know today just what may lie ahead of us, but if there ever was a time when it was necessary for each and every one of us to think clearly, today is the day.

As we face these problems that lie just in front of us, whether they be railroad problems, whether they be national problems, whether they be problems of the individual or problems of all of us collectively, we ought to face them with the knowledge that it is a challenge to our honesty and our integrity, and it should be the urge that will drive and send each one of us out into the affairs of the world, to perform our part in smoothing out the troubled waters.

I thank you for the honor. (Applause)

(President Hastings made an announcement regarding meeting of the Board of Direction.)

President Hastings: Is there any further business? If not, I declare the Fortieth Annual Convention of the American Railway Engineering Association adjourned.

(The meeting adjourned at four-five o'clock.)

American Railway Engineering Association

REPORT OF THE SECRETARY

March 1, 1939.

To the Members:

This report covers the activities of the Association during a year of drastic curtailment of railway expenditures and a reduction in railway employment. In other words, circumstances were decidedly unfavorable for growth of the Association. As a matter of fact, some ground was lost, for there was a decrease in the total membership in spite of the election of 87 new members and 8 reinstatements during the year. The Association's gross income also declined, but it was possible to make a corresponding reduction in expenditures so that the year was closed with a comfortable excess of receipts over disbursements.

Curtailment of the administrative staffs of the railways has made it increasingly difficult for members to find the requisite time to devote to committee work, or to absent themselves from their duties for attendance at committee meetings. But the fact that they have succeeded in doing so, in spite of the demands made on their time, is attested by the excellence of the reports that have been prepared for presentation at the Fortieth Annual Convention.

Finances

The financial statement for 1938, which appears on another page, may be summarized as follows:

	Budget Estimate	Actual
Receipts	$29,000	$28,421.97
Disbursements	27,400	25,240.00
Excess of Receipts over Disbursements	$ 1,550	$ 3,181.57

No direct comparison can be made between the receipts and disbursements for 1938 and those for 1937, because the expenditures for 1937 included outlays incident to the publication of the new loose-leaf Manual which had no counterpart in 1938. Similarly, the revenues were abnormally high in 1937 by reason of the receipts from the initial sales of the new Manual, which were naturally greater during the first year that this new publication became available. However, the fact remains, that there was a decline in the revenues from member's accounts and from the sale of publications (other than Manuals) during 1938, but owing to a reduction in expenditures, the year was closed with a gain of more than $3,000 in the Association's assets.

Membership

The table below is a record of the changes in the membership rolls during the year:

Members on rolls as of March 1, 1938		1938
Additions during the year		95
		2033
Losses by death	32	
Resigned	43	
Dropped	38	113
Net loss	18	1920
Membership as of March 1, 1939		1920

The Association was exceptionally unfortunate in the loss by death of 32 members, compared with 26 in 1937, and 30 in 1936. Among the deceased members, whose names are listed on following pages, was J. G. Sullivan, a past-president of the Association (1917–1918), who was elected to honorary membership a year ago. Six others were life members, of whom three—W. L. Darling, V. K. Hendricks and F. A. Molitor—were charter members.

Publications

Bulletins—In accordance with a resolution adopted by the Board of Direction at its meeting on December 8, 1937, the number of bulletins published during the last association year was reduced from eight to seven in accordance with the following publication schedule:

June–July—Monographs
September–October—Monographs and the reports of the Electrical section committees
November—Committee reports
December—Committee reports
January—Committee reports
February—Committee reports
March—The Year Book

The high standard that has been set for the contents of the Association's interim (or summer) bulletins was well maintained during the last year. Thus, the material appearing in Bulletin 404, June–July, 1938, included:

Fourth Progress Report of the Joint Investigation of Fissures in Railroad Rails, by Dr. H. F. Moore
Discussion on Stresses in Railroad Track, by Dr. A. N. Talbot
A report on Intercrystalline Cracking of Boiler Steel, by Dr. W. C. Schroeder, A. A. Berk and R. A. O'Brien

Similarly, Bulletin 405, September–October, 1938, contained a monograph by F. M. Graham that comprised a report on an extended investigation conducted by the Pennsylvania Railroad on the penetration of tie plates into crossties.

Bulletins 406 to 409, inclusive, contain the reports of 27 committees for presentation at the Fortieth Annual Convention on March 14, 15 and 16, 1939, or 4 less than were presented at the convention in March, 1938. This reduction in the number of reports is the result of the consolidation of Committees 1 and 2 as the Committee on Roadway and Ballast, and of Committees 16 and 21 as the Committee on Economics of Railway Location and Operation; the abandonment of the Committee on Shops and Locomotive Terminals; and the suspension of the activity of the Committee on Rules and Organization for one year, pending a review by the Board of Direction of the assignments and field of activities of this important committee.

This decrease in the number of committee reports has been responsible in part for a reduction of 118 pages, or about 17 percent, in the space occupied by the committee reports, compared with a year ago.

Proceedings—Vol. 39 (1938) of the Proceedings of the Association, containing the committee reports and discussions thereon at the Thirty-ninth annual convention, were distributed to the members during 1938.

Manual—The second supplement to the loose-leaf Manual, comprising 151 sheets, and covering the revisions and additions adopted at the 1938 convention, was ready for distribution on October 1, 1938.

Two year's experience in the preparation of the supplement sheets for insertion in the new loose-leaf Manual has led to the development of certain technics that will expedite the publication and effect moderate savings in the preparation of future supplements. Of primary importance to this end is the preparation of matter for publication in the bulletins in such manner as to avoid resetting of the type for use in the Manual. This will preclude the expedient of narrow parallel columns of "new" and "old" forms, for purposes of comparison, that has been frequently employed heretofore in presenting Manual revisions.

During the last year 177 copies of the new losse-leaf Manual were sold, with the result that 1,586 of the Manuals are now in the hands of members, railroad companies and others.

General—Attention is directed to changes made in the bulletins and Proceedings, which, while of a minor nature, are believed to facilitate the use of the publications by the reader.

Beginning with Bulletin 404, June–July, 1938, a new design of cover has been used which is more in keeping with modern publication standards and also provides a more legible table of contents. A further change, appearing for the first time in the committee report bulletins, 406 to 409, inclusive, is the designation of the regular committees by Arabic numerals rather than Roman numerals, as has been the practice since the Association was organized. This change, approved by the Board of Direction, will bring the bulletins and Proceedings into uniformity with a practice previously adopted for the Manual.

In the Proceedings of the 1938 Convention, the introduction of an index to the committee reports and discussions in which the committees are listed in numerical order, and a change in the typography of the regular table of contents, greatly facilitate the use of the volume for reference purposes. It is proposed to initiate some changes in the typography of the future bulletins and Proceedings which will improve the appearance of the publications without deviating in any way from the uniform type standards that have been set up for material that is intended for publication in the Manual.

Attention is directed to the fact that some of the drawings and diagrams submitted with the reports fall short of the standards set in the instructions to committees. Excellent reports are sometimes marred by unattractive and not fully legible charts and sketches. It is realized, of course, that members of committees have limited opportunity to have association work done in the overburdened drafting rooms of the railroads, but every effort should be made to improve the standard of drawings for AREA illustrations.

The Work of the Committees

The work of the Association is done through the agency of its 22 regular and 5 special committees and the results accomplished are clearly apparent to anyone who reads the reports prepared by these committees, appearing in Bulletins 406 to 409, inclusive.

Depending primarily on the nature of the assignments, these reports vary widely as to both subject-matter and scope, some of them being confined to a single consolidated statement while others include detailed presentations on as many as 12 subjects.

In all, the committees have presented reports on 116 assignments, and these reports not only cover a broad range of subject-matter, but they differ widely with respect to the disposition of the assignments. For the purpose of affording an idea of the type of reports presented, an effort has been made to place them in several classifications or groups, as is indicated in the following paragraphs. The classification is an arbitrary one, which in some cases involved the placing of a report in one group which might perhaps have been placed just as well in some other category.

By far the largest group of reports is that which embraces subjects on which the committees have presented general or specific information, there being 36 of these in all.

Manual material is covered by 29 items, exclusive of recommendations relating to minor revisions. Of these 29 items, 12 each cover new material and extensive revision of material now in the Manual, and 5 comprise specifications and practices that are submitted in tentative form for criticism.

Six assignments comprise mathematical studies and nine others are of the nature of analytical studies leading to specific recommendations.

Evidence of the volume of research being carried on directly on or through collaboration with other organizations is afforded by 13 reports that comprise statements of current progress on various projects or which present detailed test data. These reports are supplemented by 4 others that embrace valuable statistical material.

Mention must be made also of four standing assignments on which committees report the current status of certain development from year to year. There are also 4 bibliographies, and 11 brief reports of progress.

Scheduling of Committee Reports

In accordance with the plan adopted in 1937, the committee reports were published according to a schedule that is designed to place in the same bulletin, reports that are to be presented at the same convention session. The advantage of this plan is that it makes it unnecessary for members to bring more than one, or possibly two, of the bulletins to any one convention session.

To carry out this plan it has been necessary to set a rather rigid schedule of dates for the filing of the completed committee reports with the secretary. However, owing to the excellent co-operation received from the committees in meeting the completion dates set it was possible to publish the bulletins strictly on schedule. As a result of this experience it appears possible to make some adjustment in the schedule during the present year so that the committees may be allowed from one to three weeks more time in which to complete their reports.

Collaboration With Other Organizations

While most of the work of the Association relates to engineering problems that are peculiar to the railroads, it also involves many matters in which other organizations have an equal if not more direct interest. Because this condition might easily lead to duplications of effort or conflicting recommendations, the Association has long since adopted the policy of collaborating with other groups in projects of mutual concern by the appointment of representatives to participate in the studies and investigations conducted by these other organizations.

Because of the large number of projects involved, their highly diversified nature and the fact that new ones are being created while others are being brought to a conclusion

it is difficult to maintain an accurate, complete and up-to-date record of these activities. A check, made during the past year with the co-operation of the committee chairmen, was productive of the list given below, which shows the names of organizations with which the Association collaborates by the appointment of representatives to participate in specified projects.

Name of Organization	Number of Projects
American Association of State Highway Officials	1
American Transit Association	2
American Society for Testing Materials	11
American Society of Civil Engineers	1
American Society of Mechanical Engineers	1
American Society of Municipal Engineers	1
American Welding Society	1
Central Committee on Lumber Standards	1
Engineering Foundation	1
Highway Research Board	1
Joint Committee on Standard Specifications for Concrete and Reinforced Concrete	1
Joint Committee on Boiler Feedwater Studies	1
Joint Committee on Railway Sanitation	1
National Bureau on Engineering Registration	1
National Bureau of Standards, U. S. Department of Commerce	1

It is of interest to observe that 22 members of the AREA, represent 8 AREA committees on 11 committees of the ASTM.

The foregoing tabulation relates only to those activities in which the members participate in the interest of the AREA. Many others serve as representatives of the Engineering division, AAR, on a variety of collaborations, of which the most extensive is that embraced by the work of the American Standards Association.

Miscellaneous

An amendment to the Constitution, proposed by the requisite number of members and consisting of revisions of Article II, Membership; Article III, Admission, Resignations, Expulsions and Reinstatement; and Section 2 of Article IV, was submitted to the voting members of the Association by letter–ballot on April 1, 1938. The result of the ballot was as follows:

For the amendment	509
Against the amendment	16
Defective ballots not counted	20

The Constitution, as amended, was published in the Proceedings for 1938 (Vol. 39) and appears also in Bulletin 410, March, 1939.

Upon the recommendation of the secretary, a re-arrangement of the Association's offices in the Buckingham building, Chicago, involving a modest outlay, was authorized. This has resulted in a much more effective utilization of the space available and in a better co-ordination of the work of the staff.

In completing this report of his first year's service with the Association, the secretary wishes to express his appreciation for the valuable counsel and assistance he has received from the members of the Board of Direction, for the efficient co-operation accorded by the chairmen of committees, and for the spirit of loyalty and helpfulness that has been manifested by the members of his staff.

W. S. Lacher,
Secretary.

Deceased Members

A. W. Armstrong
President, The Wood Preserving Corporation

E. L. Bahls
Office Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad

H. S. Blake
Assistant Engineer, Norfolk Southern Railroad

Edward Capouch
Contracting Engineer, American Bridge Company

H. S. Clarke
Engineer Maintenance, Delaware & Hudson Railroad

F. R. Coates
Member, Executive Committee, Henry L. Dougherty & Company

H. C. Crowell
Assistant to Chief Engineer, Pennsylvania Railroad

W. L. Darling
2100 Englehart Avenue, St. Paul, Minn.

J. H. Dymock
Supervising Engineer, Ministry of Transportation
Ullapool by Garve, Ross–Shire, Scotland

R. A. Feldes
Assistant to Vice-President, New York Central System

J. W. Foote
General Superintendent, Niagara Junction Railway

Andrew Gibson
(Retired) General Superintendent Timber Preservation, Northern Pacific Railway

F. W. Gilcreast
Consulting Engineer, Lehigh & New England Railroad

H. C. Goodrich
Chief Engineer, Bingham & Garfield Railway

E. J. Gurski
Assistant to President, Midland Continental Railroad

H. J. Hansen
Office Engineer in Charge of Bridge Design, Chicago, Milwaukee, St. Paul & Pacific Railroad

Deceased Members

V. K. Hendricks
736 South Oak Park Avenue, Oak Park, Illinois

J. B. Jenkins
Valuation Engineer, Baltimore & Ohio Railroad

Noah Johnson
Roadway Engineer, Wabash Railway

R. L. Latham
Chief Engineer, Toronto, Hamilton & Buffalo Railway

L. B. Lincoln
Principal Assistant Engineer, Bangor & Aroostook Railroad

Frederick Mears
Assistant Chief Engineer, Great Northern Railway

F. A. Molitor
Consulting Engineer

A. H. Morrill
Chief Engineer, Boston & Maine Railroad—Maine Central Railroad

F. H. Neff
Professor Emeritus of Civil Engineering, Case School of Applied Science

M. P. Paret
Lake Charles, La.

L. W. Skov
Hydraulic Engineer, Chicago, Burlington & Quincy Railroad

J. B. Strauss
Consulting Engineer

J. G. Sullivan
Consulting Engineer

C. E. Weaver
General Manager, Central of Georgia Railway

W. G. Wieand
Track Supervisor, Reading Company

J. B. Young
Engineer of Tests, Reading Company

GEOGRAPHICAL DISTRIBUTION OF MEMBERSHIP

United States and Possessions

Alabama	13	Nebraska	22
Arizona	3	New Hampshire	3
Arkansas	11	New Jersey	35
California	49	New Mexico	1
Canal Zone	1	New York	156
Colorado	19	North Carolina	17
Connecticut	25	North Dakota	1
District of Columbia	30	Ohio	152
Florida	11	Oklahoma	8
Georgia	24	Oregon	7
Hawaii	1	Pennsylvania	149
Idaho	1	Puerto Rico	1
Illinois	293	Rhode Island	3
Indiana	33	South Carolina	2
Iowa	22	South Dakota	1
Kansas	29	Tennessee	20
Kentucky	30	Texas	73
Louisiana	12	Utah	4
Maine	7	Vermont	8
Maryland	35	Virginia	86
Massachusetts	42	Washington	15
Michigan	46	West Virginia	21
Minnesota	60	Wisconsin	13
Mississippi	8	Wyoming	1
Missouri	106		
Montana	5		1715

Other Countries

Canada	101	Manchukuo	3
Japan	19	Czechoslovakia	2
Mexico	12	Bolivia	1
Australia	10	Colombia	1
Brazil	9	France	1
England	8	Germany	1
Argentine	6	Norway	1
China	6	Peru	1
Central America	6	Poland	1
India	4	Siam	1
Union Soc. Sov. Rep.	4	Switzerland	1
Africa	3		
Cuba	3		205

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1938

Balance on hand January 1, 1938		$78,229.28
RECEIPTS		
Membership Account		
Entrance Fees	$ 880.00	
Dues	17,724.52	
Binding Proceedings	1,503.75	
Sales of Publications		
Proceedings	1,063.50	
Bulletins	1,134.32	
Manual	1,835.73	
Specifications	655.76	
Track Plans	300.85	
Advertising		
Publications	689.60	
Interest Account		
Investments	1,999.56	
Profit on bond called for redemption	500.00	
Miscellaneous	38.95	
Structural Pamphlets	95.43	
Total	$28,421.97	
DISBURSEMENTS		
Salaries	$ 7,608.09	
Proceedings	4,307.43	
Bulletins	4,518.09	
Structural Pamphlets	83.50	
Stationery and Printing	1,199.47	
Rents, Light, etc.	832.70	
Supplies	41.39	
Expressage	148.35	
Postage	495.50	
Exchange	86.27	
Committee Expense	16.37	
Officers' Expense	18.55	
Annual Convention	960.93	
Refunds, dues, etc.	63.50	
Audit	200.00	
Pensions (E. H. Fritch—A. K. Shurtleff)	2,460.00	
Social Security Act	76.08	
Manual Supplements	1,053.72	
Track Plans	614.07	
Miscellaneous	412.00	
Accrued Interest, etc., on Bonds Purchased	44.39	
Total	$25,240.40	
Excess of Receipts over Disbursements		3,181.57
Balance on hand December 31, 1938		$81,410.85

REPORT OF THE TREASURER

To the Members:

Balance on hand January 1, 1938		$78,229.28
Receipts during 1938	$28,421.97	
Paid out on Audited Vouchers, 1938	25,240.40	
Excess of Receipts over Disbursements		3,181.57
Balance on hand December 31, 1938		$81,410.85
Consisting of		
* Bonds at cost	$74,939.56	
Cash in Northern Trust Company Bank	5,725.13	
Cash in Royal Bank of Canada	721.16	
Petty Cash	25.00	
	$81,410.85	

* Includes $6,240.00 book value of Rock Island, Arkansas & Louisiana 4¼ percent bonds due March 1, 1934, not paid, in default.

Also includes St.L.S.W. 5 percent bonds, book value $1,319.31, interest coupons January 1, 1936 and thereafter in default.

Respectfully submitted,

W. H. Penfield, *Treasurer.*

We have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1938, and find them to be in accordance with the foregoing statements.

E. Deming,
C. G. Rivers,
Auditors.

GENERAL BALANCE SHEET

December 31, 1938

Assets	1938	1937
Due from Members	$ 1,467.50	$ 1,416.25
Due from Sales of Publications	38.15	60.00
Due from Advertising	50.00	35.00
Furniture and Fixtures	300.00	338.00
Gold Badges	.....	25.00
Publications on hand (estimated)	2,000.00	2,000.00
Extensometer	.....	150.00
*Investments (cost)	74,939.56	67,868.31
Interest on Investments (accrued)	641.25	410.00
Cash in Northern Trust Company Bank	5,725.13	10,142.45
Cash in Royal Bank of Canada	721.16	193.52
Petty Cash	25.00	25.00
‡Manual Revision Work (suspense)	.....	11,774.74
Manuals (on hand)	4.200.00	.....
	$90,107.75	$94,438.27
Liabilities		
Members' Dues Paid in Advance	$ 5,194.00	$ 5,167.75
Surplus	84,913.75	89,270.52
Total	$90,107.75	$94,438.27

* Includes $6,240.00 book value of Rock Island & Louisiana 4¼ percent bonds due March 1, 1934, in default.

Also includes St.L.S.W. 5 percent bonds, book value $1,319.31, interest coupons January 1, 1936 and thereafter, in default.

Commonwealth Edison Company, First Mortgage 5 percent bonds due July 1, 1953, called for redemption June 13, 1938, at $110.00 plus accrued interest.

U. S. Treasury Notes, par value $12,000.00, purchased for $12,071.25 during year 1938.

‡ In accordance with action of Board of Direction, dated December 13, 1938, the amount of $11,774.74, carried in suspense as of December 31, 1937, has been written down to the approximate asset value of Manuals on hand, and the difference of $7,574.74, charged to surplus in year 1938 account.

THE NEW ENGLAND FLOODS, HURRICANE AND OCEAN STORM OF SEPTEMBER, 1938

An Address by C. E. Smith

Vice-President, New York, New Haven & Hartford Railroad, New Haven, Conn.
Presented before the American Railway Engineering Association on March 14, 1939.

New England is not the usual habitat of hurricanes or floods. Although it is well acquainted with gales, principally the Nor-Easter, their principal effect is on ships at sea. There are records of only three hurricanes since white men settled in New England, viz:—in 1635, 1815 and 1938. Neither is New England the home of floods, although central New England suffered from unprecedented floods in 1927, 1936 and 1938.

In September, 1938, however, southern New England suffered simultaneously from floods in the interior, the hurricane of unpleasant memory and the ocean storm that struck its southern coast. On September 17 occurred the coincidence of the start of four days of heavy rainfall, reaching as much as 15 in. in Connecticut and Massachusetts, and, on the same date, the start of the hurricane north of Porto Rico.

During the next four days the rains continued until, during September 20 and 21, many miles of the Rutland, the Central Vermont, the Boston & Maine, the Boston & Albany, and inland lines of the New Haven were washed out. During the same period the hurricane headed north and west toward Cape Hatteras, veered to the northeast, apparently headed for its normal destination in the Atlantic, but suddenly and unexpectedly veered to the north and struck Long Island and the New England coast about 3:00 p. m., on September 21, followed by unusually high water lashed by the high winds to the fury of an ocean storm.

Cut a Swath Through New England

The hurricane center struck between New London, Conn., and Providence, R. I., and cut a swath northerly through Connecticut, Massachusetts, New Hampshire and Vermont, with plenty of wind to spare in Maine on the east and New York State on the west. The ocean storm caused the water to rise 15 to 20 ft. above normal high tide on the Connecticut and Rhode Island shores and several feet at New York harbor.

The floods affected all the railroads mentioned. The hurricane affected them all in decreasing amounts as the hurricane spent itself on land in northern Vermont and Canada. Only the New Haven's shore line between New York and Boston, Mass., and the south end of the Central Vermont north from New London were affected by the ocean storm.

When the hurricane struck, orders were issued to stop all freight trains in the interest of safety. Passenger trains proceeded slowly to points of safety, clearing the tracks of houses, boats, trees, poles and other debris. All reached safety on high ground before the ocean storm moved in except one train of 13 cars with over 300 passengers.

On September 20, the fourth day of heavy rainfall, the inland lines of all the railroads began to go out because of floods, and a serious situation was presented on the morning of September 21. After the hurricane and ocean storm on that day they were paralyzed except the Boston & Maine's lines to the north and northeast, which were kept open principally to handle foods and other necessary supplies for Boston and vicinity, and excepting the Boston suburban service of three railroads and the electrified line of the New Haven between New Haven, Conn., and New York City. Inland floods washed out many miles of railroads and highways, including bridges.

And just to complete the picture, the Connecticut river continued to rise with the flood waters from above and inundated main lines, until the river began to recede after cresting at Hartford, Conn., at 7:00 p. m., September 23. The main lines north of Hartford came out of the water at 10:00 a. m. September 25.

The Coast Guard fleet stationed at New London found shelter in a cove behind one of our drawbridges, but a large barge was wrecked and sunk under the draw so it could not be opened. The fleet stayed there for some time until the channel was cleared by dynamiting, which nearly wrecked the bridge.

Boats of various sizes were deposited on the New Haven's main track along the shore, the most disturbing of which was the lighthouse tender "Tulip" which occupied one main track at New London for two weeks and barely cleared the other track.

No Adequate Advance Notice

New Englanders received no adequate advance notice that the hurricane would strike New England. The Providence Journal listed the following warnings, issued by the U. S. Weather Bureau:—

September 20—10:30 p. m.
Northeast storm warnings from Virginia capes to Atlantic City.
September 21—10:00 a. m.—Received Providence 11:08 a. m.
Northeast storm warnings north of Atlantic City and south of Block Island. Southeast storm warnings Block Island to Eastport, Maine.
September 21—12:30 p. m.—Received 1:50 p. m.
Whole gale (55 to 75 m.p.h.) Atlantic coast north of Virginia capes to Sandy Hook, moving rapidly north or slightly east.
September 21 3:00 p. m.—Received at Providence at 3:40 p. m.
Warning northwest from Virginia capes to Sandy Hook. Tropical storm central at 1 p. m. about 75 miles southeast of Atlantic City moving rapidly N.N.E. Storm center will pass over Long Island and Connecticut late this afternoon or early tonight.

At 3:00 p. m. when this warning was issued the hurricane had already struck Long Island and Connecticut. Had adequate warnings been received less lives would have been lost, less damage done to boats and less damage and inconvenience to passenger trains. The damage to fixed property would have been as great.

The hurricane warning was received at New Haven at 3:05 p. m. and at Providence at 3:40 p. m., practically coincident with its arrival. At 5:00 p. m. water from Narragansett bay poured into the streets of Providence to a depth of 10 ft., in about two hours, over one square mile of the downtown retail district, submerging the first floors of hotels, theatres and stores of all kinds. Here the water rose 15.3 ft. above mean high tide. About three miles of waterfront were inundated but this entire mess cleared up in two weeks.

To understand the intensity of the damage, attention is called to the density of population of southern New England in comparison with Florida, the home of hurricanes and with Missouri and Illinois.

	Area Sq. Miles	*Population*	*Population Per Sq. Mile*
Florida	54,861	1,575,000	28
Missouri	68,727	3,678,000	53
Illinois	56,043	7,876,000	140
Mass., R.I. and Conn.	13,926	6,700,000	478

It would be possible to put all of the New Haven and the Boston & Maine into the state of Missouri, south of the Missouri river. The New Haven handles about as much traffic as the Missouri Pacific.

The hurricane blew down all power and communication lines and hundreds of thousands of trees, top-heavy with wet leaves, standing in soil saturated by the long continued rains, were uprooted. The hurricane also destroyed or damaged hundreds of buildings by unroofing or collapsing them, breaking windows, destroying steeples, etc.

The ocean storm completed the damage by destroying or damaging over 50,000 houses and killing 700 people. A disastrous fire destroyed much industrial property at New London.

The flood, hurricane and storm damage was characterized by its widespread extent and the many points damaged, some of which could not be reached by rail or highway until after extensive reconstruction of lines leading to them.

As reported by the Boston & Maine—"By September 20, reports were simply pouring in—'Rivers rising; Slides over track; Bridge gone; Still raining; Water over track; River over track; Train marooned; Derailment at.....'; until it almost seemed as though nothing worse could happen.

"But the elements performed a final trick by producing a hurricane on the afternoon of September 21. The pictures that faced the operating department the next morning were not entirely pleasant. It was, in all probability, the most serious situation in the history of the Boston & Maine."

When the Hurricane Struck

When the hurricane struck, the New Haven's shore line between New York and Boston and its line between New Haven, Conn., and Springfield, Mass., had not been affected, and five B. & A.—Boston-Chicago—passenger trains were being detoured over the New Haven between Springfield, and Boston via New Haven and Providence. Those trains and nine New Haven passenger trains were caught and marooned by the hurricane and ocean storm.

In the cold gray dawn of the morning of September 22, as reports began to filter in, the Boston & Maine was confronted with 266 major washouts, 40 bridges and culverts destroyed or damaged, 22 land slides and 45 submerged locations. The Boston & Maine was damaged more seriously by the floods, lost more important bridges and suffered worse washouts than the other railroads. The New Haven suffered more from the hurricane and ocean storm.

On the New Haven there were 17 miles of railroad washed out in 250 separate places, 45 bridges destroyed or damaged, and 240 buildings destroyed or damaged, as well as widespread destruction of signal and communication lines. The situation was duplicated proportionally on the other railroads.

Fourteen passenger trains with between 3,000 and 4,000 passengers were marooned on the New Haven and out of communication with any headquarters for 12 to 24 hours. In the New York harbor the hurricane tore two New Haven barges away from a tug and dashed them against the Brooklyn army base, sending six cars overboard.

Water eight feet above normal along the coast between New York and New Haven put out of business three power plants that supply power to the New Haven's electric division, but the division continued without interruption with power from another New York Harbor steam plant and hydro-electric power from the Connecticut hills.

The unusually high water in New Haven harbor overflowed the yard and covered the main line track leading east and north from New Haven several feet deep. After water in the harbor dropped enough so that ground separated it from the submerged tracks, pumps operated all night September 21, handling 20,000,000 gal. of water, uncovering the tracks at 2:50 p. m. on the following day.

The United States Lighthouse Tender "Tulip" Resting on the Main-Line Track of the New Haven at New London, Conn., Following the Hurricane.

The following is a description story of the situation at Providence and on the Rhode Island coast where the worst damage resulted from the storm that followed the hurricane:—

From "The Great Hurricane and Tidal Wave—Rhode Island," September 21, 1938 (published by the Providence Journal Company.)

At 3 o'clock in the afternoon of September 21, the Weather Bureau here reported winds of 40 to 45 m.p.h., and 10 min. later by telegraph to the Journal office from a news service came a hurricane warning, to the effect that the tropical disturbance would cross Long Island sound and reach the Rhode Island—Connecticut border 'early tonight'.

In Providence, pedestrians were then having difficulty keeping their footing. Trees began to crash. Telephone and electric light wires were down in a hundred spots. The utility companies were flooded with calls. There is, perhaps, a touch of wry humor in the call that came to the Providence Journal office. A woman wanted to complain that a tree had fallen on her property, and the forestry department wouldn't do anything about it.

Not until later was the picture of fast-approaching fury on the coastline pieced together, for even in midafternoon communication was difficult. At Westerly, Charlestown, all along the exposed South County shore, the wind began to build up at 2:30 o'clock, the surf rose high, and at 3:30 p. m., more than three hours before scheduled high tide, the Atlantic had reached its expected high water mark. It was an evil omen of what was to come.

Even as the weather-wise mind began to grasp the implications of these coincidental circumstances, the waters of Narragansett bay, driven by a 121-mile-an-

hour wind, piled into the upper bay, squeezed into the restricted reaches of the harbor, overflowing in great surges as they came, and topped the ramparts of the Providence river in the very heart of the city at about 5 p. m.

So swift was the onrush that time and incident were lost. In Market square and vicinity—including the great banking and business structures there—thousands of persons were marooned on upper floors. Within 10 min., the river-head area was a great mass of water whipped by hurricane wind. Within 30 min. there was a depth of six feet at that sector which is cut through by Union street in the Providence business section.

The waters rose, and the whole downtown area took on the appearance of a nightmare. Trapped people leaped from buses and cars. They waded knee-deep, bending their bodies to a screaming wind. They struggled waist-high in water, and the waters still rose. They were chin-deep in places where yesterday they had shopped, eaten lunch, stopped to talk with friends. They swam, swam for their lives, and many were saved only because refugees in second floors flung them ropes and hauled them up from the wind-whipped flood.

Hundreds of automobiles were submerged, their tops two feet below the surface. Department stores, banks, hotels, restaurants, shops of all kinds, were flooded nearly to the ceiling of the first floors. Basement machinery was completely smothered, and at the peak, the waters rose to just over 13 ft. above mean high water, lapping at the sides of buildings in low spots eight to ten feet above gutter levels and flooding as far west in the downtown area as the edge of LaSalle square.

Heavy Rip Rap Failed to Hold the Roadbed Slopes on the New Haven's Shore Line.

Effect of the Floods on the Main Tracks of the New Haven at Putmann, Conn., In This Case the Entire Fill Under the Track Was Swept Away.

But though a staggering story of flood was told in Providence, it paled in comparison when the frightful picture of death and devastation on the coast from Westerly to Little Compton materialized through the abating storm.

From Watch Hill to Narragansett, the South County shore's playground for all classes of people, was devastated. Great sections of it had been wiped from the map. Its beaches were gouged out by surging seas.

But, worst of all, from the communities of Watch Hill, Misquamicut, Quonochontaug, Charlestown Beach, Green Hill and Matunuck, scores of persons, and in some cases whole families, had been swept to their deaths. Not a beach home was left standing at some of those gay shores, and the beach itself upon which the dwellings had stood was ground down and swallowed by a furious sea made mad by wind.

Men came from that area who had their families snatched from their very grasp by raging waters, and they swore they saw a tidal wave 100 ft. high, white-crested and breaking, as the land tugged at its base.

They did see waves of tide, driven by a wind that reached 121-miles-an-hour velocity at the peak of the storm; waves that mounted to 30 ft. or more in height under the triple influence of wind, the hurricane suction of water, and the tripping of the rolling masses as they, in succession, felt the drag of land rising sharply from the ocean depths.

A general check up started soon after the peak of the hurricane in the early evening of September 21.

Trees, poles, houses, boats and debris of all kinds covered many miles of track. Fourteen drawbridges were without power and the electric machinery and motors soaked, signal and electrical facilities everywhere badly damaged by salt water.

Passenger trains had to be located and the passengers taken care of.

It was nearly 24 hours later, on the afternoon of September 22, when fairly complete information about the condition of the railroad, and the location and condition of marooned passenger trains, was reported by employees who had worked their way over the damaged sections.

Although all the passengers and crews who went through the storm have thrilling stories to hand down, only one of the 14 passenger trains experienced any trouble.

Train No. 14 (the Bostonian) proceeding easterly on the block behind Boston & Albany first No. 8, had passed a caution signal and stopped at a red light approaching Stonington, Conn. The engineman contacted the signal operator 600 ft. away, only to discover that signals were out of order, whereupon he returned to his train to proceed cautiously, following B. & A. first No. 8. In the meantime, rising waters had started to undermine the rear cars which began to settle and lean, and floating debris had set the brakes. Passengers were ordered to move ahead in the train. When this had been accomplished, the head end car with 275 passengers was cut off by Mr. William F. Donoghue, general chairman of the Brotherhood of Railway Trainmen, standing nearly to his neck in water, and the car was drawn to higher ground.

Unfortunately, all passengers did not heed the instructions of the crew to remain on board. Some of them were induced by a passenger to leave the train and fight their way to high ground through the rising waters, with some distressing experiences, including the drowning of one passenger and one dining car employee. Had they remained on the train, no lives would have been lost and no one would have been injured.

In the late afternoon and evening of September 21, immediately after the hurricane, work trains were started in all directions from as many points as possible, and representatives were started out over the highways in automobiles to learn what they could and do what they could to restore service. Within 24 hours, on the New Haven, about 5,000 men and all equipment owned by the railroad or which could be hired were busily at work.

Every operation was conducted continuously night and day by forces of the operating, mechanical, bridge, track, signal, communication and all other departments. Starting on the morning of September 22, four quarries went on a 24-hour basis until they had shipped over 5,000 carloads of rock. The purchasing offices, storehouses and material yards operated continuously day and night. In addition to shipping from stock, over 500 emergency orders were placed, several of our regular supply houses keeping men on duty continuously to meet our emergency calls.

The other railroads proceeded similarly.

Inland routes were re-opened on September 28. Shore line passenger traffic was resumed on September 23 with a motor bus relay of 36 miles between New London, Conn. and Westerly, R.I., reduced to 18 miles on September 25. That 18 miles was not closed until October 5, just two weeks after the storm; and pending a cleanup of the freight accumulation, full passenger service was not restored until October 9. In the meantime, all rail service had been restored on September 28 by the Boston & Albany and the New Haven between New York and Boston, via Springfield.

On October 9 the New York-Maine trains and on October 13 the Montrealer and Washingtonian resumed through service between Washington, D. C. and Montreal, Que.

On October 24 the New Haven's all-parlor-car extra-fare trains, the Merchants and Yankee Clipper, were restored on their limited schedules between New York and Boston via the rehabilitated shore line.

The principal burden of rehabilitation and restoration of operations fell on the operating departments, principally on the engineering departments, of the railroads in-

How Debris Was Piled Up on a New Haven Bridge at Norwich, Conn.

volved, but all departments took hold with a will. I have never experienced a better degree of co-operation nor higher morale all along the line than was evidenced by accomplishment during this trying period.

The extent of the physical damage and the problems presented will be shown by lantern slides of scenes on the New Haven and the Boston & Maine, the latter kindly loaned to me by Mr. W. F. Cummings, chief engineer of the Boston & Maine.

[At this point the lantern slides were shown.]

Boston & Maine Damage

The damage to the Boston & Maine required much heavier reconstruction than on the New Haven, because the former operates through more mountainous country in northwestern Massachusetts than the New Haven, which operates principally on the sea coast and over gently rolling hill country in Connecticut, Rhode Island and eastern Massachusetts.

During heavy rains extra track patrols were sent out on the Boston & Maine, notwithstanding which early in the morning of September 20 a freight train was derailed by a land slide at Deerfield Junction in western Massachusetts, and at 10 o'clock that night, a passenger train—Boston to Montreal—was derailed by a washout.

During that night and all the next day and night reports were received of main line bridges and abutments and piers destroyed or seriously damaged, washed out culverts, track buried under slides, washed off the roadbed, and completely washed out to various depths for long stretches, extensive flooding of track and property, signal telephone and telegraph system, centralized traffic control and automatic train control seriously damaged or destroyed.

All That Was Left of a Boston & Maine Bridge After the Failure of a Dam.

Boston & Maine detour freight moved over Canadian lines 421 miles farther than usual to reach Boston, and the B. & M. received less revenue because of its short haul and low division. A total of 4,271 freight car loads was handled this way.

The B. & M. employed 3,600 regular and extra men, 40 units of heavy work equipment, cranes, shovels, ditchers, pile drivers, spreaders, etc., and roadway machines of all sorts; also contractors' forces and equipment used both on temporary and permanent repairs. Gravel pits operated continuously and the purchasing department worked 24 hours a day to furnish piling, timbers, food, clothing, lighting equipment, tools, implements and materials, aided by the Maine Central and the Delaware & Hudson.

On October 1, the line was opened between Rotterdam and Troy, N. Y., through to Greenfield, Mass., thence via the Connecticut River line north to Bellows Falls, Vt. and Ashburnham, Mass. to Boston, and via White River Junction and Concord to Boston.

A train that under normal conditions called for one engine and one crew over the B. & M. regular main line required three engines and five crews over detour routes.

Of 1,000 road miles out of service:

279 miles were returned in 2 days.
535 miles were returned in 4 days.
672 miles were returned in 7 days.
760 miles were returned in 10 days.
795 miles were returned in 12 days.
816 miles were returned in 15 days.

On October 23, one month and two days after September 21, the main line was restored for its full length.

The greatest damage to the B. &. M. was between Gardner, Mass., north of Worcester, and Hoosac tunnel in northwestern Massachusetts, as follows:

Between Gardner and Miller's Falls, near the Connecticut river, 31 locations of major damage in 34 miles.

Between West Deerfield, Mass., near the Connecticut river, and East Portal, 18 locations of major damage in 23 miles.

Buildings were damaged extensively.

Damage between Gardner, Mass. and Millers Falls was caused by Millers river and tributaries.

Bridge 99—Gardner, Mass., 14-ft. 5-in. span over a highway. Failure of a dam washed out the roadbed for 330 ft. to a depth of 10 ft.

Bridge 101—Otter River, Mass., deck plate girder, ballast deck—38 ft. long, 17 ft. high. Both abutments undermined and partly washed out. Built detour trestle, pending construction of abutments.

Between West Deerfield and East Portal, Mass. Damage was caused by the Deerfield river and tributaries.

Bardwell—location on the side of a mountain. Difficult to hold fill. Shoulder out 80 ft. by 3 ft.; bank cracked 50 ft.; two tracks washed out 270 ft. by 60 ft.; shoulder slip 250 ft. by 3 ft.; two tracks washed out 90 ft. by 20 ft.; shoulder slip 500 ft. by 5 ft.

Water from mountain side repeatedly washed out new fill and crib. Had to install catch basin and drains to river before fill could be restored.

The Boston & Maine had 266 washouts, 22 land slides, 45 submerged locations and 27 bridges destroyed or damaged. The rebuilding of six bridges involved 6,000 cu. yd. of earth excavation, 1,400 cu. yd. of masonry excavation, 5,500 cu. yd. of concrete masonry, 1,200 lin. ft. of cofferdam and 18,000 sq. ft. of steel sheet piling left in place, 220 foundation piles, and immense quantities of riprap. The work of rehabilitation involved 1,300,000 man-hours of labor, 1,500 work-train days, 15,000 carloads of filling and many thousands of feet of timber and piling, and the cost of rehabilitation was $2,200,000.

Subsidized Transportation

The last picture illustrates a very important point. An oil tanker, handling oil up the Hudson river in competition with the New York Central and other railroads, is stuck in the ice, i.e., interfered with by weather conditions. A Coast Guard boat, supported by taxpayers, is engaged in breaking up the ice to free the tanker. Thus the federal taxpayer contributes to the cost of transportation of oil by water and enables it to be performed at less than its whole cost. But no agency of government supported by taxpayers came to the relief of the New England railroads nor even of other railroads when weather conditions interfered with their operations. They free their property at their own cost.

The September damage to the New England railroads amounted to $6,500,000 which they paid out of their own resources. The corresponding damage to highways was estimated at $25,000,000, all of which will be paid by the taxpayers, and thus highway transportation is enabled to render service at less than its whole cost in competition with the railroads that must charge the whole cost of railroad transportation.

There is a story that when, in the late lamented twenties, a Mr. Newlyrich asked Mr. J. P. Morgan how much it cost to keep a yacht, Mr. Morgan replied "If you need to know, you should not have one."

A Coast Guard Boat Engaged in Breaking Up the Ice to Free a Tanker Which Transports Oil by Water at Low Rates in Competition with the Railroads Which Pay Their Own Way.

I am sure that if the taxpayers knew how much it cost them to provide facilities and service for our competitors, they would not have it, and each would find its natural place in the economic picture.

All public utility improvements such as highways, railroads, waterways, power lines, telephones, water and gas, serve important social needs in a community but in no case should the taxpayer be charged with the cost of providing such service.

The United States District Court (Southern District of Illinois) has said:

> "The highway system owned by the state and its subdivisions is a public utility supplying facilities which constitute an actual monopoly which is subject to intergovernmental regulation and control. The annual cost of operating such utility should be determined in the same manner as for a privately owned public utility."

Dean Marston of Iowa State College has said:

> "Our highways are simply great public utilities comparable to publicly owned power and light plants, water works and the like. So-called highway taxes and fees are comparable to the bills against customers of power and light plants for the services rendered them individually."

Roy W. Crum, director of the Highway Research Board, has said:

> "The concept of highways as public utilities is sound, and I believe that established principles of public utility management could well be applied to highway finance and administration."

Our highway competitors make much capital out of the fact that they are paying large amounts in registration fees and gasolene fees that they call taxes, when in reality they are an inadequate payment for the use of the facilities provided and maintained at the cost of the taxpayers. Up to quite recently no one has had any very definite information as to the cost to the taxpayers in excess of the amounts paid by the highway users, but fortunately two recent studies have thrown considerable light on that subject.

The Highway Department of the State of Illinois has recently determined, with the approval of the federal courts, that it is costing the state and governmental subdivisions of the state $116,000,000 per year to provide highways, for the use of which $52,000,000 is paid by those using them, leaving a deficiency of $64,000,000 per year, a direct subsidy contributed by the taxpayers.

More recently a committee of consulting engineers, Messrs. Clifford Older, D. W. Downs and C. B. Breed, have determined that for a 12-year period, 1921 to 1932 inclusive, the total cost of providing highway facilities was $20,876,146,000, of which the general taxpayers should have paid $5,087.797,000 but did pay $14,844,751,000. Further, that motor vehicles should have paid $15,788,349,000 but did pay only $6,031,-395,000, resulting in a total subsidy to the highway users by taxpayers during that period of $9,756,954,000.

While this is the most complete and comprehensive study that has yet been made, no one really knows the full extent of the cost to the taxpayers of providing and maintaining highways and carrying expenses incident to highway traffic, because no one has yet included in any study the cost of traffic policing, traffic lights, courts, hospitalization and other costs due to accidents, earlier renewals than would otherwise be necessary, widening of streets, traffic ways in cities, excessive maintenance, etc., but the true facts are gradually coming to light.

The taxpayers contribution to the cost of waterway transportation not only covers the operation of the ice-breakers shown in the photograph, but also the investment of funds in and tax exemption on such facilities as the Erie canal, Cape Cod canal, improvement of inland waterways, coastwise channels and harbors, and the losses incurred by barges operated by the government on the Mississippi river and its tributaries. The destruction of railroad values by such subsidized competition is tantamount to confiscation without compensation, directly contrary to the principles on which our great nation was founded. It is a national scandal. Under similar government competition any industry would become bankrupt.

There is no sufficient reason from an economic standpoint why the users of these highway and waterway facilities should not be charged tolls for their support. This would in no way encroach on the right of navigation to use natural waterways, but when they are artificially improved by the expenditure of the taxpayers money, the taxpayers should be reimbursed by tolls for the support of the expenditures.

The airlines are also heavily subsidized at the expense of the taxpayers by arbitrary amounts paid by the government for carrying mails, free weather service, lights and beacons, and public airports maintained by the taxpayers.

Magnitude of the Subsidy

No completely dependable estimate has ever been made as to the total amount of these subsidies to the competitors of the railroads, but if the facts could be all gathered, it would not surprise me if the total should be $2,000.000,000 per year.

The railroads in the early days were compelled by various devices to protect the traffic and revenues of their competitors. By contrast, the three principal competitors of the railroads today—the highways, waterways and airways—are heavily subsidized at the general expense of taxpayers in a way that permits the competitors of railroads to render service to shippers and passengers at less than the total cost of the service in competition with the railroads which must account for the total cost of their services without aid from the taxpayers. That is a principal reason for the desperate plight of the railroads, second only to lack of traffic due to continued depression in industry.

A great deal is heard about diversion of amounts collected from highway users to other purposes than the direct provision of highways for their use. The reasoning is deficient inasmuch as the amounts talked of are usually only the amounts contributed to state governments and the amounts spent by state governments. No reference is made to the tremendous amounts contributed by the federal government, and by subdivisions of the state. The contentions as to diversion could be supported with better grace were the users of the highway actually paying all they should pay for their use of the highways.

Inasmuch as the taxpayers are contributing nothing to the support of the railroads, it would be much more logical for the railroads to demand that all the taxes paid by the railroads be spent on the railroads and not diverted to any other use.

Of course if that argument were followed to its logical conclusion, each activity of government would have to be taxed separately and the taxes applied only for the purpose for which levied, and we would have a separate police tax, fire department tax, school tax, hospital tax, street tax, library tax, park tax, pension tax, court tax, poor tax, and indeed an indefinite number of taxes, each covering a separate activity of government.

Following the reasoning of the non-diversionists it might be appropriate to inquire if the hospital tax would be levied only on the sick, the prison tax only on the criminals, the poor tax only on the poor, or just where does this line of reasoning lead. Of course, the reasoning of the non-diversionists is absurd. The users of highways and waterways should not only be charged with all costs incurred on their behalf by government agencies, but they should also be taxed as are others for the general support of government that cannot be taxed directly against privileged users.

What of Land Grants?

We hear a lot from our competitors that railroads should not complain about subsidies to them inasmuch as they state that the railroads were heavily subsidized in the past. That this is not so is easily demonstrated. The government land grants to the early railroad promoters were not subsidies, they were really advances conditioned on the railroads saving the government in transportation rates what now amounts to substantially five percent perpetually on the value of the lands. The investments of the government in early railroad construction were not subsidies but were loans secured by the bonds of the railroads.

The advances by the government to the railroads during and immediately following the World War were not subsidies but were secured loans carrying interest. The funds the government has been advancing to the railroads during the present depression are not subsidies but are secured loans carrying interest.

None of these financial contacts of the government with the railroads has cost the taxpayers any money. On the other hand, the government is reaping annually excellent returns on the value of the lands granted to the early railroad promoters, secured a fine profit on the loans made the railroads during and following the World War, and there is no reason to believe that they will lose anything on the current loans. Taxpayers have not in the past contributed continuously to provide facilities to enable the railroads to render service at less than the whole cost. On the other hand, the aid that is currently granted our competitors is direct subsidies which cost the taxpayers large amounts of money and do enable the competitors to render their transportation service at less than the whole cost, with serious effects on the railroads, banks, insurance companies and other investors.

ECONOMIC BALANCE OF COMPETITIVE FACTORS

A Vital Need For Transportation Recovery

An Address by C. E. Johnston

Chairman, Western Association of Railway Executives

Presented Before the Annual Luncheon of the American Railway Engineering Association on March 15, 1939

I find it a pleasure to be accorded the opportunity of addressing you here today. My own service in the engineering and maintenance field, my years as a member of this organization, and my privilege of such a personal acquaintance with many of you that I address you by your first names, combine to make me feel that I am among those of my own kind who know me and will understand my viewpoint.

It requires a definite effort on my part to resist the temptation to indulge in reminiscence and to recall to your memory the subjects with which we were concerned when I first began attending these meetings several years ago. I well remember the time, I think it was during the World War, when I was all steamed up over our labor situation. I felt it so keenly that I wrote the then president of this organization, expressing myself quite forcibly, that I thought the situation almost unbearable and that something should be done about it and suggested more activity on the part of the committee assigned to the job. His reply was both courteous and quite understandable, and was to the effect that from that date on I was to be a member of the labor committee. I was later the chairman of that committee for a period of three or more years.

We realize that vast and fundamental changes are steadily taking place in the railroad industry. This has been going on for several years and from the railroad standpoint, has created many difficult problems. What we choose to call the "depression" has added greatly to our difficulty. Generally speaking, you, as railroad engineers, like all others in the railroad business, are seriously concerned with the vital problems confronting the industry and in their proper solution. The field or scope is too great for me to undertake here to discuss all of them, so I shall do my best to give you my analysis of at least some of the difficulties in which we find ourselves today and, at the same time, indicate certain special fields of service in which you may be of assistance in the solution of these problems.

Railroads Need More Traffic

Primarily, it is my firm belief that perhaps our greatest fundamental difficulty is the need for more traffic or business. By that I do not mean to say that we should relax our efforts in any other direction, but I do mean that, in my opinion, our industry now suffers from no difficulties which a greater traffic volume would not remedy, if not cure. Our survival and our further development depend, first, upon the existence or creation of a sufficient volume of transportation business which we call "traffic" and, second, upon our ability to extend to the public, service and rates sufficiently inviting to attract a larger proportion of the total traffic, so essential to the welfare of the railroads.

We all agree that our railroad transportation system is most necessary to the welfare of the American people, and that the maintenance of this system to high standards is more than justified. I need not mention here what our railroads mean to the people of this country from the standpoint of industrial and agricultural development, employment of people, purchase of materials and supplies, national defense and support of Government. The American railroads, like every other segment of American life, have

a vital stake in the peace and prosperity of our country. They prosper with the communities served, and, after all, our community is the nation.

Aside from these obvious truths, however, we must face the facts as they exist today. The facts are—the railroad industry is suffering from malnutrition brought about largely by unfair competition supported more or less by Government.

Notwithstanding the fact we have been passing through a long period of depressed business of most every nature, I firmly believe there is at the present time a much greater volume of traffic that would flow to the railroads, had we a sound and fundamental balance of the controlling economic factors. Such a balance would prevent a further shrinkage in net income, and into our situation inject that "punch" needed to lead the nation in its march toward prosperity. In my judgment, the failure to get that proper balance of the controlling economic factors results mainly from two causes—first, from our own failure to properly appreciate these facts and, second, from our failure to get the true railroad story across to the public. Everyone directly or indirectly connected with, benefiting from, or relying upon the railroad industry should know the truth and help explain it to others. I am convinced that we may depend upon the fairness and good judgment of the American people once they know the truth. Please do not misunderstand me. I minimize, in no way, the serious thought, time and effort given these subjects by numerous others, nor do I discount the many helpful and constructive suggestions which have been made. But, as I see it, in this important matter you, as members of the American Railway Engineering Association, have a duty to fulfill and may be of great assistance in accomplishing the results sought.

How Much Traffic?

We should first get an accurate estimate of the aggregate volume of existing traffic of the country, and the proportion of the total which moves by rail; then, we must consider the basic, physical and economic factors which should and ultimately will determine the division of that traffic between all legitimate carriers capable of handling it and the proportion of such traffic which the railroads should and can best handle. Once such a division is in effect the railroads will have opportunity to pass on to the public the full benefit of the truly marvelous progress made by the railroad industry during the past decade.

There appear to be no accurate figures available as to the total volume of traffic moving in America today because only the railroads afford a reliable statistical basis for calculation. While airways, pipe lines, waterways and buses account for a large volume of traffic, it is generally conceded that the highway motor truck is the most damaging competitor of the railroads. Commissioner Splawn of the Interstate Commerce Commission estimates that the common carrier, contract carrier and privately operated trucks account for four billion two hundred million dollars per year in freight revenue. Some statisticians for the railroads estimate the amount handled by trucks at about one billion dollars per year; another statistician for the Interstate Commerce Commission, basing his figures on production trends, estimates the amount handled by trucks at between six hundred million and something in excess of a billion dollars per year.

Our own research department of the Western Association of Railway Executives, basing its figures on studies by the United States Bureau of Public Roads, the Bureau of the Census, and studies of the cost of operating trucks in truly competitive service, estimates that the railroads each year lose traffic handled by trucks which, if carried by the railroads, would produce additional revenue of something near two billion dollars. This last figure seems to be checked by the truckers' own estimates, as the National Highway Users Conference claims annual revenue for trucks at two billion dollars, al-

though they have apparently included revenue from all trucks whether they are, or are not, competitive with the railroads.

Whatever the figure may be, we must recognize the truck as an increasingly important railroad competitor, particularly so when consideration is given to the fact that only approximately three and one-half billion dollars is the revenue taken in per year by all the railroads for all kinds of freight handled.

It seems difficult for even our railroad people to realize and grasp the full extent to which this competition has grown during the past few years and to understand that unless something is done quickly to stop this growing and unfair competition of whatever kind it may be and which should not exist, the railroad industry as a privately owned and operated institution is doomed. This situation has been permitted to grow worse and the time has arrived when only through organized, concerted, and honest effort and action may we expect to save the industry and our people from governmental ownership and operation.

From the figures just quoted we find that the freight traffic, handled annually by the railroads and trucks competing with railroads, produces revenue of approximately five and one-half bilions of dollars under existing business conditions, yet the railroads now get but about 63 percent of that traffic. The trend in percentage is downward and will probably continue that way until real effort is made by the government and the states to apply sound, impartial economic principles in the entire field of transportation. This is not only fair to the railroad industry and all that goes with it, but would react directly to the benefit of the public.

Let us now inquire into the basic economic factors which should be considered in balancing the traffic between available carriers. Both service and rates are questions considered by the shipper in determining the routing of his traffic. While service may be the influencing factor in the short-haul field and in the movement of some commodities, we are convinced that, in the longer haul and with reference to the bulk of the commodities, rail service and truck service are sufficiently comparable to leave rates as the controlling consideration.

Railroad Versus Truck Rates

Let us look next at the economics of railroad rates versus truck rates.

In the United States, in 1937, railroad freight and passenger revenue consisted of 88.4 percent received from freight and only 11.6 percent from passengers; and while only 38.7 percent of the total freight revenue was produced from the movement of grain, products of mines, and products of forests, these same commodities amounted to 65.6 percent of the tonnage. Of course, weight is by no means the only element of railroad cost, and long years of experience have proven the wisdom and necessity of classifying railroad freight for rate-making purposes. It is significant to note, however, that it is only in the higher-rated classifications that the railroads experience the devastating inroads of truck competition.

While ordinarily, we would not concern ourselves with the internal affairs of our competitors, it must be realized, first, that governmental regulation of railroads is based on the theory that railroads enjoy a monopoly, but that such monopoly no longer exists; and, second, that our competitors depend for their existence upon the use of thoroughfares provided at public expense and which were constructed primarily for use by passenger automobiles and for farm-to-market service and the local distribution of goods. In fact, railroads themselves make important tax contributions toward the construction and maintenance of many of the very roads used by their competitors. It is both our right and our duty to examine the facts to determine whether we, as railroads,

and our competitors upon the highways in their use of roads for purposes of competition, are receiving equal and fair treatment at the hands of the public and the effect such treatment may have upon the division of the traffic so essential to our continued existence.

We are not disposed to stand in the way of progress, but progress must be judged by sound and impartial economics. I believe that our friends in the highway transport field will agree with me that:

1. Those who use highways for the long-haul transportation of freight should pay their fair share of the capital cost of construction of roads and of the current cost of maintenance.
2. That they should make their proper contribution to the general expense of schools and other functions of government.
3. That they should not use vehicles unduly destructive to the roads over which they operate.
4. That they should not conduct operations which are unduly hazardous or which unreasonably interfere with highway use by passenger cars or those in local farm-to-market service.
5. That they should not conduct operations which are unnecessary and which so add to the existing surplus in transport facilities as to be inconsistent with the public interest.
6. That laws pertaining to these subjects should be enforced with some reasonable degree of efficiency.

All these are obviously fair and fundamental conclusions, yet in no single place in America, so far as I know, is there any semblance of law which translates them into fact. The forum for the correction of these evils is not alone in the Federal Congress. The responsibility likewise rests upon the shoulders of the several states. In fact, in only a few states is there any approximate knowledge of the actual yearly cost of public highways or the fair apportionment of that cost among the vehicles which use them. In the few states where knowledge of these basic facts exists, the tax charges levied against individual vehicles bear no remote relationship to the proportion of highway cost which they should bear.

In Illinois, for example, studies by the state division of highways show that the state incurs for the heavy duty truck an annual cost of $1,361.28, and collects from that same vehicle in all kinds of fees only $364.56. Studies in states less densely populated show that the subsidy is even greater. I hold it is utterly obvious if the automobile owners and the property tax payers of the several states are to continue to finance our competitors to the tune of approximately $1,000 per year per truck, railroads cannot be expected to continue for very long as private institutions deprived of equal sustenance from the public tax trough.

"Taxes" Paid by the Trucks

Not only does the public seem to be unaware of the fact that trucks, generally, fail to pay their share of the cost of the facilities provided for them by the public, but there seems to be little realization of the fact that that enormous trucking industry is almost wholly escaping its contribution to the expense of government and the general welfare. Much is said about the "taxes" paid by the trucking industry. Although you and I may know the facts, the public does not seem to realize that those payments, for the most part, are not taxes at all; that they are merely inadequate contributions toward the enormous expense of providing special facilities, (highways), for their special use; and that little, if any, of the proceeds of those payments is used for the maintenance

of our schools and the general functions of government. In Nebraska, for example, the railroads last year paid the sum of $3,476,648 in property taxes while their truck competitors paid only $162,469 in comparable charges. In 1937 (I do not have the figures for 1938) the railroads paid $1,700,000 in school taxes in that state.

Studies further show that trucks and trailers of unreasonable sizes and unnecessarily heavy weights are prematurely destroying some of our finest highways; that they are permitted to unreasonably interfere with highway use by passenger cars; that they conduct numerous operations which are plainly inconsistent with the public interest; and that many of the laws pertaining to such operations are, all too frequently, more honored in their breach than in their observance. All these circumstances combine to give to the truck an unwarranted and unfair advantage in the struggle for traffic.

These conditions make it possible for the truck to make uneconomic inroads on the volume of the more lucrative traffic and to consequently shift to the basic or staple commodities an undue share of the burden. In other words, the farmer, the miner, the lumberman, and those who consume their products, must bear a greater proportion of the fixed cost.

No one maintains that there is no place for the motor truck in the transportation picture. It is recognized as both a useful and necessary instrument in its proper sphere. The point I mean to make is that, through a lack of knowledge and understanding of the facts and as the result of apparent public apathy, many truck operations have been permitted to expand into unnatural fields and to carry on services which are not only unnecessary, but downright harmful to the public interest.

It is a conservative estimate, (and under existing circumstances no man alive can do more than guess) that if the several states and the federal government could be prevailed upon to promptly and impartially equalize the competitive factors outlined above and to bring about reasonable efficiency in the administration and enforcement of the laws pertaining to them, there would be automatically returned to the railroads of America from one-fourth to one-half of the traffic now moving by truck.

The Task That Needs to Be Done

Let us then consider the task that needs to be done to bring all these things into being. We cannot and must not resort to wishful thinking. Appeals to public sympathy will be of no avail. Effective results are usually actuated by selfish motives. We are confronted with the colossal task of selling to the American public the selfish wisdom of a square deal in transportation; an understanding of the fundamentals of transportation economics. We must provoke an appreciation of the meaning of, and results from, an increase of from one-half billion to a billion dollars a year in railroad revenues. We must make the business man feel the stimulus of a tremendous revival in railroad purchases—to see the flame and smell the smoke belching forth from blast furnaces—and to hear the shriek of the new locomotive as it rolls along the glistening new rail. We must make the shipper understand the ratio of fixed to variable costs and appreciate the actuality of reduced rates and improved service which flow from an increase in traffic volume. We must allow the motorist his sigh of relief at the smoothness and freedom of driving over highways uncluttered and undamaged by lumbering trucks engaged in hauling much freight which really should move by rail. And, finally, we must bring Mr. Average Man to visualize that it is money in his own pocket when he ceases to help subsidize an operation which nets him little or no return.

To do all this we must be honest and sincere in our purpose, accurate in our calculations, sure of our facts, patient and painfully persistent in our efforts, and our

arguments must carry the conviction which springs from honesty, simplicity, directness and understanding.

As engineers you must share the responsibility with all the rest of us, but your special training with a comparatively exact science and the mental discipline which characterizes your work make you peculiarly adapted to perform a vital part in this great undertaking. I sincerely trust that in planning your affairs you may find it consistent to devote adequate emphasis to the conduct of work which will enable us to know the facts, simplify their analysis and provoke public understanding.

So much for the economic balance of competitive factors. In closing, I shall make reference to certain of your other important duties which are specific and individual to you and your profession. Among these specific duties we find the subject of roadway maintenance in which so many of you are vitally interested.

Needless to say you have had much to contend with during the past several years. By sheer necessity the pressure has been great to keep down cost and you have responded nobly to these commands. I know of no better demonstration of courage, loyalty and good judgment on the part of those directly in charge. As I see the picture, this demand is likely to continue for an indefinite period and we may as well make the best of it which I am sure you will do.

It is, therefore, essential that particular attention be paid those important fundamental items of the physical property—the track structure. I have in mind roadbed, ballast, ties, rail and bridges. Once any of these items are permitted to slip as to condition of maintenance, the entire track structure is weakened. In other words, it is comparable with the strength of a chain and its weakest link.

The tendency is definitely toward greater speed in both passenger and freight service. There is now a public as well as a very great competitive demand in that direction. You are the people almost directly responsible for the safety of such operations in that you have the responsibility of roadway maintenance.

Therefore, my suggestion is that in the interest of safety and maintenance of high standards, you constantly bear this in mind since you or your property cannot well afford a condition otherwise.

What of Labor?

At this same time I shall say a word about labor. You know the importance of this subject in all its aspects, but you should never forget that we are dealing with the human element.

Many things have happened during the past few years to cause a decided change in the attitude of labor, with which we must deal in railroad maintenance. I am happy to say, however, that we still have a large measure of fair mindedness and loyalty among our employees, particularly in our supervisory forces. So long as this exists, and I have no reason to feel it will not, we may well base our hope on improvement.

May I suggest continued care and watchfulness in the selection of our foremen and other supervisors for, in my judgment, therein lies the secret of our success in the maintenance department.

Summing up, I will say that while the railroad industry has had and is having adversity, there is nothing that causes me to feel that we are licked or to give me a defeatist attitude. If I know our engineers, they never are "licked," so, where do we go from here?

There's just one way to go and that's straight ahead, bearing down all the harder, with more long hours, more constructive effort and more good old common sense thinking. That's the real spirit and the real American way of doing things.

REPORT OF COMMITTEE 26—STANDARDIZATION

E. M. Hastings, *Chairman;*
J. R. W. Ambrose,
John E. Armstrong,
Hadley Baldwin,
F. L. C. Bond,
A. E. Botts,
J. G. Brennan,
H. F. Brown,
H. M. Church,
B. W. DeGeer,
John Foley,
C. F. Ford,
C. J. Geyer,
J. B. Hunley,
C. A. Knowles,
J. A. Lahmer,
J. F. Leonard,
H. G. Morgan,
John V. Neubert,
W. G. Nusz,
G. P. Palmer,
Arthur Ridgway,
F. S. Schwinn,
H. M. Stout,
Dr. A. N. Talbot,
R. A. Van Ness,
G. R. Westcott,
O. G. Wilbur,
A. R. Wilson,
Committee.

To the American Railway Engineering Association:

Your committee was given three subjects for study and report:

1. What AREA recommended practices should be advocated for general use on railroads.

2. What AREA recommended practices should be sponsored as projects for National Standardization.

3. Maintain contact with standardization bodies and keep the Association informed on important matters developed by such contact.

Your committee reports progress on all three subjects.

1. What AREA recommended practices should be advocated for general use on railroads.—Because of the few changes that would be made in the tabulation of items selected by your committee as worthy of careful study by members of the Association for uniform use, which tabulation is Appendix A in the Proceedings, Volume 38, page 466, it is not felt that the re-publication of the list in this report is warranted. Your committee again recommends to the members that a study of the recommended practices and specifications as set forth in the above mentioned Appendix and found in the Manual of the association, is worthy of careful consideration. Your attention is directed, in using the tabulation, to the few Manual changes which have been made since the publication of the report.

2. What AREA recommended practices should be sponsored as projects for National Standardization.—Your committee has not recommended any projects during the past year nor does it have immediately before it any projects to recommend.

3. Maintain contact with standardization bodies and keep the Association informed on important matters developed by such contact.—These contacts have been continued as heretofore and a brief resume of the activities of the American Standards Association, which has been furnished your committee by Mr. A. R. Wilson, Association of American Railroads representative in American Standards Association; also a resume of the activities of the Canadian Engineering Standards Association, which has been furnished by Mr. W. R. McCaffrey, secretary of that association, follow:

Bulletin 406, November, 1938.

AMERICAN STANDARDS ASSOCIATION (ASA)

The American Standards Association again appreciates the interest of the Association of American Railroads in its financial support and the assistance its representatives have given in the many sectional committees, the Association of American Railroads being represented in the Standards Council.

Representatives

Div. I—Operating; W. A. Jackson (term expires December 31, 1940) (Mr. Jackson succeeded Mr. Rodgers during the past year).

Div. IV—Engineering; A. R. Wilson (term expires December 31, 1939).

Div. V—Mechanical; J. E. Ennis (term expires December 31, 1938) (Mr. Ennis succeeded Mr. Cantley during the past year).

Alternates

Div. IV—Construction and Maintenance Section; W. F. Cummings and E. M. Hastings. Electrical Section; Sidney Withington. Signal Section; E. K. Post.

Div. V—Mechanical; K. Cartwright.

Div. VI—Purchases and Stores; C. B. Tobey.

The record of the American Standards Association in the past year has been one of growth—in membership, in work, in the methods by which the work is accomplished.

In the last 12 months 16 new national groups have affiliated—marking the largest increase in membership in any year since the association was organized.

Through the American Standards Association as a national clearing-house, the work of trade associations, technical societies, and other independent groups is being welded together into a consistent set of national standards, in the development of which every interested group has a part.

Approval by the American Standards Association, requiring a 90 percent affirmative letter ballot vote of the representatives of some 40 national bodies on the Standards Council, brings with it acceptance by a large number of groups that otherwise might not have had contact with the standards, broadening the use of the standard and increasing its effectiveness.

In the electrical field, the regular bi-annual revision of the National Electrical Code has been approved. Further work completed in this field includes Specifications for Insulated Wires and Cables; for Railway Motors; and for other Rotating Electrical Machinery.

In the mechanical field the new American Standard for Large Rivets has been approved, bringing to completion 11 years work on the part of manufacturers, users and technical experts. During the year four important machine tool standards have also been completed.

Through the work of the recently organized Building Code Correlating Committee, the ASA has an opportunity to perform a real service in harmonizing the many conflicting building regulations now in use.

An important administrative achievement was completed by the Standards Council during the year—revision of the rules of procedure under which the association has operated since 1928.

The "Manual of American Standards approved by the American Standards Association" with prices of standards may be secured free on application to the American Standards Office, 29 West 39th Street, New York City.

CANADIAN ENGINEERING STANDARDS ASSOCIATION (CESA)

Civil Engineering

Portland Cement—Revision of Specification A5–1927 is in progress.

Concrete and Reinforced Concrete—Preliminary arrangements have been made for the revision of Specification A23–1929.

The work of the committee on National Building Code, under the National Research Council, has resulted in requests for the following standardization by the CESA:—

Standard Fire Tests on Building Construction and Materials.

Specifications for several types of Water and Sanitary Pipe.

Specifications for Brick, Building Blocks and Mortar Materials.

Reorganization of the CESA Committee on Building Materials is under way, due to these requests, and organization of special subcommittees and panels for the work on the required specifications will follow.

Mechanical Engineering

Safety Code for Passenger and Freight Elevators. This code (B44–1938) was ready for publication in April.

Screw Products—Binder Head Screws. Agreement was reached among the interests concerned with No. 10 Binder Head Screws. A revision slip was prepared for insertion in Specification B35–1933 dealing with this subject.

Logging Chains. Satisfactory progress is being made.

Axes for Forestry Purposes. Recommendations have been received to establish a standard on this commodity and progress is anticipated during the coming year.

Safety Code for Mechanical Refrigeration. The CESA has been requested to review and adopt the tentative Refrigeration Code "JCRQ 38–3" prepared by a joint committee in the Province of Quebec. A CESA committee has been organized for the purpose.

Boiler Code. The Committee on Steel Plate for Boilers and Pressure Vessels has been renamed Committee on Canadian Boiler Code. Review of the ASME Boiler Code is under way by this committee.

Galvanized Steel Wire Strand. Meetings of the committee working on the revision of Specification B12–1924 were held and the third draft of the proposed revised specification was prepared for letter ballot approval.

Identification of Piping Systems. The committee working on the preparation of this standard have submitted their second draft specification which has been sent out to interested organizations for comment.

Electrical Engineering

Canadian Electrical Code, Part I (Inside Wiring Rules). It is anticipated that the fourth edition will be published about the end of 1938.

Canadian Electrical Code, Part II (Approvals Specifications for Electrical Appliances and Equipment). Specifications for specific appliances and equipment are issued from time to time as separate publications under Part II. They are prepared by the Panel on Specifications, the membership of which comprises a comprehensive representation of interests. At the present time active work is in progress on 10 or 12 specifications and some 20 or more are listed for attention as time and facilities will permit.

Canadian Electrical Code, Part III (Outside Wiring Rules). Overhead Systems—The special panel working on this specification has now provided a second draft which will be distributed for comment to various interests. This second draft has been broken down into two parts—one applicable to Power Supply Lines and Trolley Lines Crossing Railways, the other especially prepared for Communication Lines Crossing Railways.

General Standards in Section C

Paper-insulated Lead-covered Cable. This specification passed through several drafts and was advanced for final approval prior to publication. Objections to certain clauses raised by some of the power companies, however, have caused delay in publication.

Tungsten Incandescent Lamps. The second draft of the second edition of Specification C 10 is in preparation.

Aluminum Cable and Aluminum Cable (Steel Reinforced). A committee has been organized to prepare a standard specification under this heading.

Control of Radio Interference. A special subcommittee, under the chairmanship of Mr. W. P. Dobson, was appointed from the Committee on Canadian Electrical Code to determine the part that the CESA should take in regard to establishment of standards for measuring the degree of interference and for equipment that may be used in its control.

Revision of Procedure—Canadian Electrical Code. In order to eliminate the possibility of confusion or complication in matters of procedure relative to establishment of specifications or regulations, or in the matter of revisions, a special subcommittee was appointed, also under the chairmanship of Mr. Dobson, to review the present procedure and recommend revisions.

Arrangements were made to call a general conference of representatives of provincial and municipal inspection bodies early in the new fiscal year for the purpose of co-ordinating eastern and western viewpoints on matters pertaining to the Canadian Electrical Code.

Ferrous Metallurgy

Reinforcing Materials for Concrete. The committee working on specifications under this subject completed the revision of the following specifications which will be issued shortly:

G30–1930—Billet-Steel Reinforcing Bars (second edition)

G31–1930—Rail-steel Reinforcing Bars (second edition)

G32–1930—Cold-drawn Steel Wire for Concrete Reinforcement (second edition)

New standards ready for publication:

G45—Fabricated Steel Bar or Rod Mats for Concrete Reinforcement

G46—Welded Steel Wire Fabric for Concrete Reinforcement

Steel Construction

Steel Highway Bridges. On March 31, 1938 revised Specification S6–1938 had reached page-proof form, preparatory to early publication. This third edition has been transferred from the Civil Engineering Section A to Section S, Steel Construction. Likewise, A1–1928 "Steel Railway Bridges", and A16–1930 "Steel Structures for Buildings", which are under revision, will eventually be published under Section S in their next editions.

Structural Welding. The following standards were in page-proof form and were submitted to the main committee for approval to publish:

S47–1938 T—Welding Qualification Code for Fabricators, Contractors, Supervisors and Welders for Welded Steel Buildings.

S48–1938 T—Metallic Arc (Iron and Steel) Electrodes for Welded Steel Buildings.

Since these standards are in a field where knowledge is limited, it has been decided to issue them as "Tentative" until their value has been tested over a period of a year or so, when revision can be made if advisable to bring them into line with practical experience. It is of importance to note that these standards refer specifically to "Welded Steel Buildings" and do not include general welding requirements.

Suggestions had been received to broaden the scope of these standards to include all types of steel structures and mechanical equipment, but it was finally decided to confine the scope to steel buildings during the time that the standards are in tentative form.

Working Committees (New or Reorganized)

Two new working committees were organized during the year, viz.:

Committee on Aluminum Cable.
Committee on Canadian Boiler Code.

In addition to the above, three old committees were reorganized, viz.:
Committee on Incandescent Lamps.
Committee on Wire Strand.
Committee on Wood Poles for Transmission Lines.

Reference has been made, during the work of the various committees, to analogous publications of the British Standards Institution, Associations of other British nations, American Society for Testing Materials, American Standards Association, National Electrical Manufacturers' Association, the Underwriters' Laboratories, and other standardizing bodies.

Your committee does not present as a part of this report a list of the standards approved by the ASA during the year nor do we present for publication the tabulation of ASA technical projects on which the AAR is now co-operating with the names of co-operating members. The reason for not publishing this latter tabulation, which appears as Appendix C, page 471, Proceedings, Volume 38, slightly revised by report on page 68, Volume 39, is due to the fact that there have been quite a few changes in the representation of the railway associations and we have not been able to complete a thoroughly revised tabulation. Such a revised tabulation could not be accurately prepared until after January 1, 1939.

The Committee on Standardization,
E. M. Hastings, *Chairman.*

REPORT OF COMMITTEE 18—ELECTRICITY

H. F. Brown, *Chairman;*
D. J. Brumley,
D. M. Burckett,
F. W. Gardiner,
Paul Lebenbaum,
W. L. Morse,
R. J. Needham,
A. E. Owen,
H. W. Pinkerton,
J. S. Thorp,
D. B. Thompson, *Vice Chairman;*
W. M. Vandersluis,
R. P. Winton,
S. Withington,
Committee.

To the American Railway Engineering Association:

Your Committee was instructed to report on (1) Developments in the application of electricity to railway service, (2) the principal current activities of the Electrical section, Engineering division, A.A.R. These have been published in full in Bulletin No. 405 (September–October 1938) but are abstracted and summarized below:

Developments in Application of Electricity

During the past year, in spite of industrial conditions being at a lower ebb, with corresponding reduction in railway traffic, there have been several notable developments or trends in the application of electricity to railroads that are worthy of a brief recording, and which indicate that the railroads are doing their share in keeping abreast of the times.

In the heavy electric transaction field, mention must be made of the extension of the Pennsylvania Railroad electrification to Harrisburg, Pa., which was placed in operation since the last report of this committee. This important carrier has also increased its fleet of electric locomotives, with the addition of units similar to previous designs, and with new experimental designs. The New York, New Haven & Hartford Railroad has also acquired and placed in operation new electric locomotives of increased capacity. Mention must also be made of the electric operation of rapid transit trains over the San Francisco–Oakland bridge, and the terminal developments brought about by the operation of that important traffic link.

Further developments have been made in electronic rectifying apparatus for converting alternating current into direct current for application, not only to traction power supply, but for wayside or terminal power supply for precooling air-conditioned cars. An extensive and notable application of the latter has been made in one of the large eastern terminals, which is the first of the kind.

In connection with air-conditioning and the use of electric power on passenger cars, the "Gene-Motor" or motor-generator set, driven either from the car axle or by a.c. wayside power at terminals, is an important new development this past year.

In the field of electric illumination, the outstanding developments are the fluorescent lighting units for passenger cars, several successful installations having been made in some of the recent new equipment; the high pressure mercury vapor lamp for shop lighting, and the sodium lamp for yard and highway crossing illumination. Louvre type lighting for cars has also received further study and development during the year.

In the diesel-electric field, many carriers have added to their existing investment in motive power of this kind, possibly the most notable being the new three-unit locomotive of the Seaboard Air Line, having a total capacity of 6,000 hp. New light-weight car equipment of one western carrier includes an independent diesel-electric unit on each car for the lighting, heating and air-conditioning of that car.

Mention must be made also of the improvement and greater use of electric welding in car construction and shop practice, notable examples of the former being the new design Pullman equipment recently placed in service between New York and Chicago.

During the last year also, one eastern carrier has put into operation a section of track with the joints electrically welded, as an experiment to determine the value of this type of track construction. Continued improvement has also been made in the design and application of electrical tools for track construction and maintenance, operated from portable or wayside gas-electric generating sets.

Reports of the Electrical Section

Owing to the fact that no annual meeting of the Electrical section was held in 1938, the reports of the Electrical Section are reports of progress only; they are not complete for all assignments and have had no discussion by the membership of the Electrical section. They may be abstracted as follows:

Power Supply

The report refers (1) to the national power survey of the Federal Power Commission and to the improvements made since the last report in the design of high-pressure topping plants for increased efficiency of existing power plants, and (2) summarizes in tabular form power supply facilities installed by various systems for servicing mechanical air-conditioned passenger cars, and (3) briefly reports on the desirability of simplifying rate schedules for the purchase of electrical energy.

Electrolysis

The report on electrolysis covers the following:

(1) The practice of various electrified railroads in preventing leakage of stray currents through the foundations of catenary supporting structures.

(2) Methods which have been used to isolate return track circuits from foreign return circuits, and

(3) Methods which have been used in various parts of the country in co-ordinating studies of the electrolysis problems, with an abstract of a paper by Mr. C. M. Longfield on the stray current electrolysis in Australia, in connection with the 1,500-volt suburban systems of the Victorian Railways.

Overhead Transmission Line and Catenary Construction

Work has been continued on the preparation of specifications covering bronze and copper trolley wire, messenger wire and other component parts of catenary construction. Very little progress has been made on any of the other assignments covering specifications for supply lines crossing railways, etc., but it is hoped that important progress can be reported next year.

Standardization of Apparatus and Material

This report submits a proposed specification for rubber insulated wires and cables of No. 14 A.W.G. size and larger. It also submits a proposed specification for fiber conduit to be encased in concrete, and suggests proposed changes to ASTM specifications for friction tape which will permit the adoption of these specifications as a recommended standard for the Association of American Railroads, after approval by the American Standards Association. This report also recommends the revision of the Manual, substituting the American Standards specification and tests for rubber insulating tape for the present specification.

Electric Heating and Welding

This report presents a comprehensive procedure for the application of electric heat for re-conditioning flood damaged equipment.

Application of Motors

This report covers new developments in the motor field, mentioning in this connection new developments in fractional horsepower motors, synchronous motors, explosion-proof direct-current motors, high-speed polyphase induction motors and lighter weight single-phase motors. It also reports on the design of motor supply circuits, covering such features as the effect of reactance on the size of the feeders, the use of capacitors, the simplification of motor starters and switches, and the grounding of portable motors.

Clearances for Third-Rail and Overhead Working Conductors

The diagrams submitted with the report of this committee for last year covering overhead clearance lines for permanent way structures on electrified railways, have been slightly revised in an effort to bring them into line for adoption and approval by the Association of American Railroads.

Protective Devices and Safety Rules in Electrified Territory

The report submits a recommended practice for the prevention of electric sparks that may cause fire during the transfer of inflammable liquids. This is presented to supersede the present rules in the Manual and Circular ES 3.

Specifications for Track and Third-Rail Bonds

This report states that no progress has been made in preparing a specification for welded bonds, but that through the co-operation of a large number of electrified railroads it was possible to revise and bring up-to-date the tabulated data on bond practice first prepared in 1925 and revised in 1932. This is presented as a part of the report.

The effect on heat treated rails of applying welded bonds to the head thereof, which has been studied jointly with the American Transit Association, is discussed at length. Mention is also made of the effect on rail bonds by the various welding processes used to build up rail ends and joints, together with the effect on rail bonds of field heat treating of rail ends.

Illumination

This part of the report covers developments in incandescent lamps, which include a new high-efficiency filament lamp and a new 100-watt mercury vapor lamp, fluorescent lumiline lamps, and sterilizing lamp for producing radiation within the bactericidal portion of the spectrum, which may be used in refrigerated spaces without undue effect on the temperature. This report also discusses floodlighting installations in railroad yards, with data for design procedure for floodlighting installations, and discusses the desirable properties for floodlighting projectors.

Application of Corrosion Resisting Materials to Railroad Electrical Construction

A brief progress report is submitted of the work now being carried on by this committee. No new data are presented this year in connection with this subject.

In connection with the subjects "Design of outdoor and indoor substations" and "High Tension Cables", no reports were submitted to the Electrical section this year.

The report of the Electrical section also very fittingly includes this year an appreciation of Mr. Loren S. Wells, for many years a member of this committee, who retired from active duty with the Pennsylvania and Long Island railroads on March 30, 1938; and also includes memoirs of George W. Bebout, Joseph W. Foote and Harry C. Goodrich, active members of the Electrical section, who died during the year.

Respectfully submitted,

THE COMMITTEE ON ELECTRICITY,

H. F. BROWN, *Chairman.*

REPORT OF SPECIAL COMMITTEE ON CLEARANCES

A. R. Wilson, *Chairman;*
John E. Armstrong,
Hadley Baldwin,
A. E. Botts,
J. G. Brennan,
H. M. Church,
B. W. DeGeer,
J. F. Leonard,
H. G. Morgan,
R. A. Van Ness,
O. G. Wilbur,
Committee.

To the American Railway Engineering Association:

The assignment to your committee is as follows:

1. Revision of Manual. Progress.

2. Clearances as affected by half-through inter-track girders and structures, third rail, signal and train control equipment, collaborating with Electrical section, Engineering division, and with the Mechanical and Operating divisions. Report presented as information.

3. Provide clearance diagrams for recommended practice, collaborating with committees concerned. Progress.

On Subject (2) the report of the committee is covered by the diagram entitled "Clearance Diagram—Encroachments" with a recommendation that it be received as information, and that a note be placed in the Manual under the chapter on Clearances, calling attention to this information as appearing on p. 75 of Volume 40, Proceedings for 1939.

The Special Committee on Clearances,
A. R. Wilson, *Chairman.*

Bulletin 406, November, 1938.

Clearance Diagram Encroachments

No Encroachment when girder flange is 1'-4", or less, above Top of Rail.

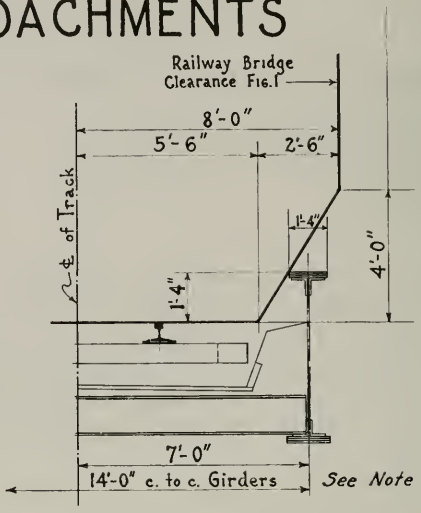

Fig. 1a

The Encroachment is determined by the girder centers when girder flange is more than 1'-4" above Top of Rail.

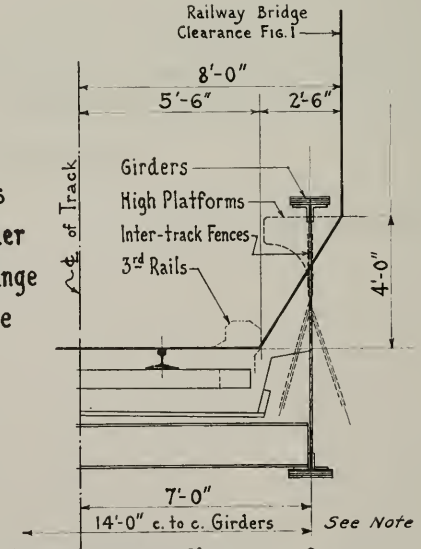

Fig. 1b

This plan shows Recommended Clearance Diagram for Railway Bridges, Figure 1, Manual page C1-2, with Encroachments by Half Through Girders, 3rd Rail, High Platforms and Inter-track Fences.

REPORT OF COMMITTEE 20—UNIFORM GENERAL CONTRACT FORMS

W. G. Nusz, *Chairman;*
E. H. Barnhart,
Clark Dillenbeck,
W. D. Faucette,
J. P. Hanley,
G. B. Harris, Jr.,
B. Herman,
J. C. Irwin,
S. L. Mapes,
A. A. Miller,
O. K. Morgan,
F. L. Nicholson,
J. S. Lillie, *Vice-Chairman;*
C. B. Niehaus,
Roscoe Owen,
H. A. Palmer,
W. M. Post,
W. R. Swatosh,
Committee.

To the American Railway Engineering Association:

Your committee respectfully presents its report on the following assignments:

1. Revision of Manual. The uniform general contract forms were fully revised prior to the publication of the present Manual and no revisions are recommended at this time.

2. Form of agreement with public authorities for highway grade crossing elimination or separation, collaborating with Committee 9—Highways. This subject was assigned to Committee 20 prior to the federal government activities in grade crossing elimination. The committee obtained many agreements from different sections of the country and gave them careful consideration, submitting a tentative form in Bulletin 371, 1935. The committee believes no final form can be submitted at this time.

3. Form of agreement to cover operation of commissary and boarding outfits. The committee submits a tentative form of agreement as information (Appendix A).

4. Form of agreement for commercial signs on railway property. The committee has collected data on this assignment and a form of contract is in preparation and will be submitted next year.

5. Form of lease for air-right development. The committee has collected information and agreements covering this assignment and considerable progress has been made. It is expected that a form will be submitted to the Association next year.

The Committee on Uniform General Contract Forms,

W. G. Nusz, *Chairman.*

Appendix A

(3) FORM OF AGREEMENT TO COVER OPERATION OF COMMISSARY AND BOARDING OUTFITS

W. R. Swatosh, Chairman, Subcommittee; E. H. Barnhart, W. D. Faucette, B. Herman, S. L. Mapes, A. A. Miller, O. K. Morgan, F. L. Nicholson, Roscoe Owen.

Your committee has collected and studied several forms of agreement covering this assignment. The following tentative draft is submitted as information and for discussion.

Bulletin 406, November, 1938.

FORM OF AGREEMENT FOR OPERATION OF COMMISSARY AND BOARDING OUTFITS

THIS AGREEMENT, made this ..... day of ..... 19..., by and between ....., a corporation organized and existing under the laws of the State of ....., hereinafter called the Company and ....., hereinafter called the Contractor.

WITNESSETH:

WHEREAS, the Company has various work to be done in connection with its business as a railroad, wherein are or may be employed numerous employees; and,

WHEREAS, the parties hereto deem it to their mutual interest that the housing, feeding and provisioning of certain employees should be regularly effected under a contract between the parties hereto;

NOW THEREFORE, in consideration of the covenants and agreements herein contained, to be performed by the parties hereto and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

THE CONTRACTOR COVENANTS AND AGREES

1. **Contractor's Control**

To assume control of and conduct in a manner at all times satisfactory to the Company, commissaries or boarding camps, at the option of the Company, at such points along the line of the Company and in such territory as the Company may designate, and board or house, either or both, the employees of the Company.

2. **Contractor's Employees**

To employ and provide at its own expense such employees as may be necessary to conduct said commissaries or boarding camps in a proper and businesslike manner, to the satisfaction of the ..... of the Company.

3. **Camp Utensils and Bedding**

To furnish at its own expense all cooking utensils, dishes, tableware, mattresses and springs (including sheets, blankets, pillows and pillow cases), keeping all such bedding properly laundered and all articles furnished or used clean and in good sanitary condition.

4. **Maintenance of Camp**

That it shall at its own expense maintain said commissaries or boarding camps and premises surrounding same in good sanitary condition, free from filth and rubbish, and maintain each or both of them so as to fully meet the requirements of the local health officers or other public authorities having jurisdiction over commissaries or boarding camps.

5. **Condition of Camp Upon Leaving**

That upon the termination of this agreement it will leave the camps and surrounding premises in a good, clean condition entirely satisfactory to the ..... of the Company.

6. **Charges Against Company Employees**

That it will not make any charge against the hereinbefore mentioned employees for lodging or rental of boarding camp or equipment in camps, where the housing accommo-

dations and equipment are furnished by the Company, except for malicious damage or destruction of same.

7. Stocking Commissaries

To keep said commissaries stocked at all times with supplies, needed by said employees, which supplies shall be sold to them at the prevailing retail prices.

8. Meals

To furnish to said employees approved meals consisting of good, wholesome, nutritious and well-cooked food of well balanced variety.

9. Alcoholic Beverages and Drugs

To prohibit the vending, and not itself vend or furnish to said employees (including its own employees) any alcoholic beverages or harmful drugs within the Company's right of way, the confines of the camp, or adjacent territory under his control.

10. Compliance With Laws

To save the Company harmless from any or all claims or liability for loss, damage or penalties for violation of any order or regulation of governmental authorities having jurisdiction or of any law or ordinance, due to the acts or neglect of the Contractor or his agents or employees in connection with the conducting of said commissary or boarding camp.

11. Fire Insurance

To secure in his own name and submit for approval to the ..... of the Company, policies of fire insurance in form and in companies satisfactory to the ..... of the Company, on the Contractor's equipment which is subject to damage as a result of fire, in such amounts as may be necessary to cover its value, and shall advise the ..... of the Company from time to time as to the amounts of insurance so carried. The Contractor shall submit policies to the ..... of the Company for approval and in case the amounts of insurance so secured by the contractor shall be deemed by the ..... of the Company to be insufficient for the adequate protection of the Contractor, the Contractor shall, when so advised, secure such additional insurance as the .... of the Company may deem necessary. It is further agreed that the Company has no right to withhold the payments of any amount due the Contractor, until the Contractor has such insurance in force and in amounts satisfactory to the ..... of the Company.

12. Indemnity

To indemnify and save harmless the Company against any and all claims, demands, suits, causes, charges, recoveries and sums of money which may arise out of, or which it may be subjected to or which may be alleged, brought, prosecuted or recovered from and against the Company, by any officer, agent, servant or employee of the Contractor, or his personal representatives, for or on account of any personal injury sustained or death suffered or resulting to any such officers, agents, servants or employees of the Contractor, while in, upon, or about any of the tracks, right of way, stations, buildings, platforms, or other premises of the Company, or upon any train or car of the Company, whether in use at the time by the Contractor or by the Company, howsoever such accident, personal injury or death may arise or may accrue, and whether the same be

alleged to be the result of the negligence of the Company, or any of its officers, agents, servants, or employees in or about the operations, maintenance, management, superintendence or control of any train, engine, car or other property or premises of the Company, or otherwise.

13. Bond

That upon the execution and delivery of this agreement, it will deliver to the ..... of the Company a good and sufficient bond in favor of the Company in the sum of $....., which bond shall be acceptable to the ..... of the Company.

14. Cost to Employees

That the price of service and meals is hereby fixed as the date of this agreement at $..... for service per week per man and ..... cents per day per meal per man. Such prices may, however, be changed from time to time by written agreement between the Contractor and the ..... of the Company.

15. Rental and Compensation

That as rental and as compensation for the right, permission, license and privilege hereby granted, the Contractor agrees to pay to the Company, during the existence of the agreement, an amount equal to one percent (1%) of the monthly deductions made for the account of the Contractor as hereinafter provided, from the pay checks of said employees, which sum shall be payable upon bill being rendered by the Company to the Contractor at the end of each calendar month during the term of this agreement.

THE COMPANY COVENANTS AND AGREES

16. Equipment, Light, Heat and Water

To furnish at such commissaries or camps the necessary buildings or cars properly equipped with bunks, stoves, including cooking ranges, refrigerators, chairs, tables, fuel, water, ice, light and toilet and drainage facilities as may be required for reasonable comfort and sanitation.

17. Transportation

That so far as it lawfully may, furnish transportation on suitable passenger trains operating over its lines, to the officers, agents and employees of the Contractor when traveling solely on the business of operating commissaries or boarding camps. The Company will furnish transportation for supplies, when such supplies are in camp cars that are to be moved from one designated location to another.

THE CONTRACTOR AND THE COMPANY MUTUALLY COVENANT AND AGREE

18. Statement to Company

That Contractor shall furnish the ..... of the Company on the fifteenth (15th) and last day of each month an itemized bill, properly certified, covering supplies, meals or service furnished each employee and the Company agrees that it will thereupon deduct from the wages due said employees respectively, at the end of each pay period the proper amount due the Contractor for supplies, meals and service during that period, and will pay over such amount to the Contractor, provided there shall be a sufficient amount due the employee, after deducting the Company's own prior items, such as hospital dues, insurance, retirement and social security taxes, etc.

19. Company's Control

The Company reserves the right to designate what points, what work and what employees shall come within the scope of this contract. The Company further reserves to each employee the right to find or provide his own meals and lodging.

20. Independent Contractor

That Contractor shall be and remain an independent Contractor with respect to all services performed hereunder and agrees to and does hereby accept full and exclusive liability for the payment of any and all contributions or taxes for social security, unemployment insurance, or old age retirement benefits, pensions, or annuities now or hereafter imposed under any state or federal law which are measured by the wages, salaries or other remuneration paid to persons employed by the Contractor on work performed under the terms of this contract and also agrees to indemnify and save harmless the Company from any such contributions or taxes or liability therefor, and further agrees to obey all lawful rules and regulations and to meet all lawful requirements which are now or hereafter may be issued or promulgated under said respective laws by any duly authorized state or federal officials.

21. Inspection

That the ..... of the Company or his authorized representative may at any and all times inspect said commissaries, equipment, supplies and food.

22. Cancellation

This agreement shall continue in force for a period of ..... from the date hereof, and thereafter until terminated by either party hereto giving to the other party at least thirty (30) days previous notice in writing of such cancellation or termination.

In Witness Whereof, the parties hereto have caused this agreement to be executed on the day and year first above written.

Attest: .....Company

..... By .....

Secretary.

Witness: .....Contractor

..... By .....

REPORT OF COMMITTEE 16—ECONOMICS OF RAILWAY LOCATION AND OPERATION

H. M. Stout, *Chairman;*
E. G. Allen,
E. Y. Allen,
B. T. Anderson,
J. A. Anderson,
S. E. Armstrong,
F. A. Barnes,
V. T. Boughton,
J. C. Bradley,
C. W. Breed,
Richard Brooke,
J. L. Campbell,
S. B. Clement,
E. B. Crane,
*H. C. Crowell,
L. E. Dale,
Olive W. Dennis,
J. H. Dyer,
H. H. Edgerton,
S. W. Fairweather,
J. M. Farrin,
R. P. Forsberg,
Geo. W. Hand,
J. L. Haugh,
R. J. Herring,
C. H. R. Howe,
G. D. Hughey,
E. A. Humphreys,
W. B. Irwin,
E. E. Kimball,
E. E. King,
Fred Lavis,
F. R. Layng,
R. S. Marshall,
F. H. McGuigan, Jr.,
Wm. Michel,
L. G. Morphy,
F. N. Nye,
J. A. Parant,
H. R. Peterson,
B. H. Prater,
J. F. Pringle,
C. P. Richmond,
M. F. Mannion, *Vice-Chairman;*
L. S. Rose,
E. H. Roth,
F. A. Russell,
J. R. Scatterday,
H. F. Schryver,
B. J. Schwendt,
O. E. Selby,
H. M. Shepard,
L. K. Sillcox,
Chester K. Smith,
H. W. Snyder,
C. B. Stanton,
J. E. Teal,
H. M. Tremaine,
R. E. Van Atta,
W. D. Wiggins,
H. W. Williams,
S. L. Wonson,
John S. Worley,
Committee.

* Died, July 29, 1938.

To the American Railway Engineering Association:

Your committee respectfully submits herewith its report on the following subjects:

1. Revision of Manual (Appendix A). Report on II Power submitted as information.

2. Methods for obtaining a more intensive use of existing railway facilities (Appendix B). Progress report.

3. Methods or formulas for the solution of special problems relating to more economical and efficient railway operation (Appendix C). Progress report.

4. Effect of volume of traffic on railway operating expenses, collaborating with Committee 22—Economics of Railway Labor (Appendix D). Progress report.

5. Methods for determining most economical train length, considering all factors entering into transportation costs, collaborating with Operating division. Progress in study—no report.

6. Effect of inland waterway transportation on the economics of railway operation (Appendix E). Progress report.

7. Effect of high speed on railway operating expenses (Appendix F). Progress report.

8. Effect of rail oiling on train operation (Appendix G). Progress report.

9. Compile operating data essential to establish units for making line and grade revisions to meet operating requirements (Appendix H). Final report.

10. Effects of speeds in excess of 75 miles per hour on the economics of railway location. Progress in study—no report.

11. Spirals required for high-speed operation (Appendix I). Progress report.

12. Grades and alinement through tunnels (Appendix J). Progress report.

13. Economics of railway location as affected by railway electrification (Appendix K). Progress report.

H. C. Crowell

H. C. Crowell, assistant engineer, of the Pennsylvania Railroad, New York City, a member of Committee 16, died on July 29, 1938. Mr. Crowell was born at Marblehead, Mass., on September 4, 1882. He received his technical education at the Massachusetts Institute of Technology, graduating from that institution in 1903.

He was a member of the American Railway Engineering Association from 1922; a member of Committee 11—Records and Accounts, from 1923 to 1927, inclusive, of Committee 21—Economics of Railway Operation, from 1927 to March, 1938 and a member of Committee 16—Economics of Railway Location and Operation from 1938 to the date of his death. He was secretary of the Board of Trade and active in the civic affairs of the city of New York.

The committee wishes to record here its appreciation of his many estimable qualities and the profound regret occasioned by his death.

The Committee on Economics of Railway Location and Operation,
H. M. Stout, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

E. E. Kimball, Chairman, Subcommittee; J. A. Anderson, S. E. Armstrong, F. A. Barnes, J. H. Dyer, J. L. Haugh, E. E. King, Fred Lavis, F. H. McGuigan, Jr., J. R. Scatterday, L. K. Sillcox, H. W. Snyder, W. D. Wiggins, S. L. Wonson.

In practice, locating and operating engineers are often handicapped in making comparisons of the economic value of various locations and gradients on account of the question of motive power, because the data which are available regarding the various types are generally meager and more or less scattered and also because the methods for computing locomotive performance are technical and quite involved.

To simplify the calculations and overcome some of these difficulties, a number of tables and forms or "Work Sheets" have been developed for obtaining the speed curves of various types of locomotives. Samples of these forms and a few examples illustrating their application are shown on the following pages of this report.

The theory of locomotive traction has been discussed in previous reports. To show the application of the theory to practice and combine the last two reports, it has been necessary to cover some of the same ground again this year along with some new applications.

II POWER

Introduction

Fundamentally, the purpose of any locomotive is to furnish power to propel trains over a railroad. The final output is composed of two factors—speed and tractive effort which are usually referred to as the characteristics of the locomotive.

(1) Tractive Effort—For the sake of uniformity in dealing with different types of motive power, tractive effort is defined as the force exerted at the driving axles to propel the locomotive.

In the case of steam locomotives it is generally necessary to be more specific because the tractive effort at the drivers is based on the cylinder or indicated horsepower after deductions have been made for the mechanical losses in the engine. It is customary to refer to these tractive efforts as cylinder or indicated tractive efforts and driver tractive efforts, respectively.

(2) Horsepower—The power developed or exerted by a locomotive is generally measured in terms of horsepower (33,000 ft.-lb. of work per minute) and, therefore, is equal to the product of the tractive effort in pounds times the speed in miles per hour divided by 375, or mathematically expressed

$$\text{Hp.} = \frac{\text{T.E.} \times \text{M.P.H.}}{375}$$

(3) Locomotive Capacity—Theoretically, the capacity of any locomotive is limited in two ways: First by the amount of power it can use, and second by the amount of power it can develop. The first limit is set by the adhesion between the drivers and the rails and hence is known as the adhesion limit. The second limit is set by the amount of power available on the locomotive, which is usually referred to as the horsepower capacity of the locomotive.

(4) Adhesion Limit—The adhesion limit depends upon the weight on drivers and the adhesion or friction which exists between the driving wheels and the rails and which is the factor that prevents them from slipping.

(5) Maximum Tractive Effort—The adhesion or adhesion factor which determines the maximum tractive effort of a locomotive depends upon rail and weather conditions. Under poor rail conditions it may amount to less than 5 percent of the weight on drivers, whereas under exceptionally good conditions it may exceed 40 percent of the weight on drivers. Poor rail conditions can be improved by the use of sand so that in practice it is generally assumed that maximum tractive efforts of 25 to 30 percent of the weight on drivers can normally be expected.

(6) Maximum Horsepower—The maximum horsepower which it is possible for any locomotive to use is set by the adhesion limit and is independent of the horsepower available, that is, the full available horsepower of a locomotive cannot be used at slow speeds without slipping the drivers, whereas at high speeds more power could be used if it were available.

(7) Available Horsepower—The available horsepower depends upon the source of power and upon the type and design of locomotive. The maximum horsepower set by the adhesion limit is proportional to the speed and can be represented by a straight line O-A in the diagrams which follow.

In the case of steam locomotives the available horsepower can be represented by a horizontal line B′C′ or BC in Fig. 1.

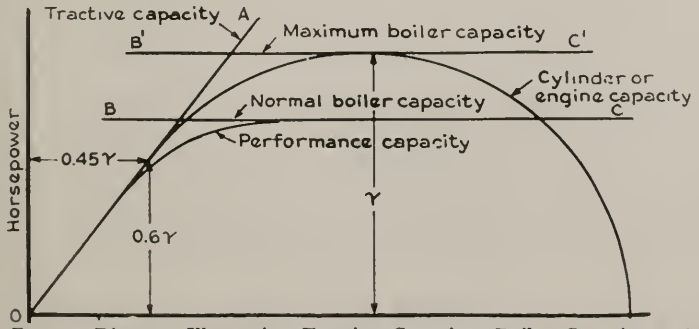

Fig. 1.—Diagram Illustrating Tractive Capacity—Boiler Capacity and Engine Capacity of Steam Locomotives.

(8) Source of Power—There are two sources of power, one is internal when the power is developed on the locomotive and the other external when the locomotive is only required to convert the power it receives from an outside source into mechanical power for application to the driving wheels.

(9) Principal Types of Motive Power—The principal types of motive power used by the railroads are steam, electric and oil-electric locomotives. The latter type also includes gas-electric rail cars and turbo-electric locomotives.

When design data are available for any of these types it is generally possible to obtain copies of their speed curves, based on actual designs, from the locomotive builders.

When design data are not available, it is necessary and feasible to base preliminary comparisons on a few fundamental factors concerning *weight, tracking qualities* and *capacity*.

In the case of steam locomotives, these three factors depend upon the wheel arrangement or locomotive classification. In the case of other types of locomotives, designing engineers have considerably more latitude in the selection of suitable mechanical constructions and wheel arrangements than is the case with steam locomotives.

For this reason it is customary to determine the representative performance of steam locomotives first and then determine the typical characteristics of electric or oil electric locomotives necessary to duplicate or improve on the steam performance. The matter can then be left with the locomotive builders to develop the mechanical details and furnish estimates of the weight and costs, etc.

STEAM LOCOMOTIVES

Locomotive Classification

Table 1 gives a list of 55 possible designs for steam locomotives grouped according to their wheel arrangements and shows how the weight of each engine is distributed. The ratios of the weight on drivers to the weight of the engine which are inherent to these wheel arrangements are shown in the second column—based on limiting the weight per guiding axle to one-half the weight per driving axle and assuming the weight per trailing axle is not less than the weight per guiding axle or more than the weight per driving axle.*

Since two or more of the types in each group overlap there is little or no demand for developing more than about 25 of the 55 designs, as shown in the third column of the table. Even some of these designs are uncommon since they have been adopted in only a few instances to meet extraordinary operating conditions.

In general, the characteristics of steam locomotives are fixed by the ratio of the weight on drivers to the weight of the engine, because the horsepower capacity depends upon the total weight of the engine, whereas the tractive effort depends upon the weight on drivers.

For example, two locomotives may have the same weight on drivers but if one weighs twice as much as the other, it would theoretically have twice as much horsepower capacity because it could carry a larger boiler. On the other hand, the maximum starting tractive efforts of the two locomotives would be the same since they have the same weight on drivers, consequently the locomotive with the larger capacity would have to develop its tractive efforts at higher speeds than the one with the lesser capacity in order to obtain any advantage from its greater power. Thus the weight on drivers is a measure of the

* This is an arbitrary assumption for the purpose of pointing out where the dividing line between different types occurs. Actually, the weight per guiding axle may be more than one-half the weight per driving axle and, likewise, the weight per trailing axle is usually less than the weight per driving axle, which accounts for the different ratios shown in the third column of the table.

TABLE 1

DISTRIBUTION OF WEIGHT FOR VARIOUS TYPES STEAM LOCOMOTIVES

2 Cylinder Locomotives

Wheel Arrangement	Ratio Weight on Drivers to Weight of Engine		Wheel Arrangement	Ratio Weight on Drivers to Weight of Engine	
	Theoretical	Practical		Thecretical	Practical
			4-8-6	.500-.572	★
4-4-4	.400-.500	.430-.470	4-8-4	.572-.667	.570-.640
4-4-2	.500-.667	.500-.570	4-8-2	.667-.800	.645-.700
4-4-0	.667-.800	-	4-8-0	.800-.889	-
2-4-4	.404-.571	-	2-8-4	.615-.727	.589-.667
2-4-2	.571-.800	-	2-8-2	.727-.889	.690-.785
2-4-0	.800-1.000	-	2-8-0	.889-1.000	.875-.926
0-4-4	.500-.667	-	0-8-4	.667-.800	-
0-4-2	.667-.800	-	0-8-2	.800-.889	-
0-4-0	1.000	1.000	0-8-0	1.000	1.000
4-6-4	.500-.600	.525-.570	4-10-4	.625-.714	-
4-6-2	.600-.750	.585-.660	4-10-2	.714-.833	-
4-6-0	.750-.857	-	4-10-0	.833-.909	-
2-6-4	.545-.667	-	2-10-4	.667-.769	.659-.715
2-6-2	.667-.857	-	2-10-2	.769-.909	.740-.840
2-6-0	.857-1.000	-	2-10-0	.909-1.000	.900-.925
0-6-4	.600-.750	-	0-10-4	.714-.833	-
0-6-2	.750-.857	-	0-10-2	.833-.909	.850±
0-6-0	1.000	1.000	0-10-0	1.000	1.000

4 CYLINDER ARTICULATED LOCOMOTIVES

4-6+6-4	.667-.750	.680-.700	4-8+8-4	.727-.800	-
4-6+6-2	.750-.857	-	4-8+8-2	.800-.889	-
4-6+6-0	.857-.923	-	4-8+8-0	.889-.941	-
2-6+6-4	.706-.800	.688-.755	2-8+8-4	.762-.842	.775-.860
2-6+6-2	.800-.923	.830±	2-8+8-2	.842-.941	.860-.895
2-6+6-0	.923-1.000	-	2-8+8-0	.941-1.000	-
0-6+6-4	.750-.857	-	0-8+8-4	.800-.889	-
0-6+6-2	.857-.923	-	0-8+8-2	.889-.941	-
0-6+6-0	1.000	1.000	0-8+8-0	1.000	1.000

★Experimental 4-cylinders.

tractive effort and the horsepower per ton on drivers is a measure of the speed of the locomotive.

Table 2 gives the approximate horsepower capacities per ton on drivers (based on three-fourths of the maximum capacity) corresponding with various ratios of the weight on drivers to the weight of the engine, also the types of locomotives which are available. The horsepowers are based upon the estimated performance capacity of modern steam locomotives equipped with the latest economy devices. In most cases the horsepowers have been obtained by discounting the maximum horsepowers obtained from tests about 25 percent in order to include reasonable margins for overloads and insure proper fuel economy. They are, therefore, subject to revision from time to time depending upon test experience and improvements in design practices. The horsepowers obtained from the table should be compared with the manufacturer's rating when available.

Examples

The following examples show a few of the applications of this table:

Example 1. Determine the approximate horsepower capacity of a modern 4–6–4 steam locomotive which weighs 200 tons (excluding tender), of which 105 tons is on drivers.

Solution—Ratio weight on drivers to weight of engine $= \frac{105}{200} = 0.525$

From the table, hp. corresponding to 52.5 percent = 36.0 hp. per ton on drivers.

Total hp. of locomotive $= 105 \times 36.0 = 3{,}780$.

Allowing a reasonable margin for overloads, the maximum horsepower expected in a test should be about $3{,}780 \div 0.75$ equals 5,040.

For preliminary estimates the total weight of the engine and tender can be obtained by dividing the weight on drivers by the percentages shown in the second column thus $105 \div 0.297$ equals 353 tons.

Example 2. Deermine the type of locomotive required if the desired capacity amounts to 5,400 horsepower and the weight per driving axle is limited to 70,000 lb.

Solution—The allowable weights on drivers for locomotives having 3, 4, 5 and 6 pairs of drivers are 105, 140, 175 and 210 tons, respectively, (70,000 times number of driving axles divided by 2,000). On the basis of 3, 4, 5 and 6 driving axles, the horsepower per ton on drivers amounts to $5{,}400 \div 105$ equals 51.4, 38.6, 30.8 and 25.7 respectively.

Consulting Table 2, the highest horsepower per ton on drivers shown for three pairs of drivers (4–6–4 locomotives) is 36.2; for 4–8–4 locomotives, 34.1; for 2–10–4 locomotives, 30.3 and for 4–6 + 6–4 articulated locomotives 25.6.

Comparing these horsepowers with the horsepowers required, it will be seen that the only locomotives in the list which are capable of developing 5,400 hp. in service are the 2–10–4 and the 4–6 + 6–4 locomotives.*

Example 3. Compare the weights of the locomotives that meet the conditions of Example 2.

	2–10–4	4–6 + 6–4
Ratio of weight on drivers to weight of engine	0.650	0.680
Ratio of weight on drivers to weight of engine and tender	0.372	0.446
Weight on drivers (tons)	175.0	210.0
Weight of engine (tons)	269.2	308.8
Weight of engine and tender (tons)	470.0	470.9
Weight of tender	200.8	162.1
Add for equal capacity tenders		38.7
Corrected weight of engine and tender	470.0	509.6

* Theoretically a 4–8–6 four-cylinder locomotive if listed would be capable of developing 37.1 hp. per ton on drivers and might be considered.

Table 2

Used for Obtaining Normal H.P. Capacities (75% of Maximum) of Typical Steam Locomotives From the Weight of Engine and Weight on Drivers

Based on Coal Fired Locomotives

Weight on Drivers Per cent		HP Per Ton on Drivers	Types of Locomotives Available			Weight on Drivers Per cent		HP Per Ton on Drivers	Types of Locomotives Available		
Wt. of Eng.	Wt. of Eng. & Tender					Wt. of Eng.	Wt. of Eng. & Tender				
41						71	40.8	28.2	2-10-4	2-8-2	
42						72	41.4	27.8	2-10-4	2-8-2	
43	24.0	40.0	4-4-4			73	42.0	27.4		2-8-2	
44	24.6	39.6	4-4-4			74	42.6	26.9	2-10-2	2-8-2	
45	25.2	39.2	4-4-4			75	43.2	26.5	2-10-2	2-8-2	
46	25.8	38.7	4-4-4			76	43.8	26.1	2-10-2	2-8-2	
47	26.4	38.3	4-4-4			77	44.4	25.7	2-10-2	2-8-2	
48	27.0	37.9				78	45.0	25.3	2-10-2	2-8-2	
49	27.6	37.5				79	45.6	24.8	2-10-2	2-8-2	
50	28.2	37.1	4-4-2			80	46.2	24.4	2-10-2		
51	28.8	36.6	4-4-2			81	46.8	24.0	2-10-2		
52	29.4	36.2	4-4-2	4-6-4		82	47.4	23.6	2-10-2		
53	30.0	35.8	4-4-2	4-6-4		83	48.0	23.2	2-10-2		
54	30.6	35.4	4-4-2	4-6-4		84	48.6	22.7	2-10-2		
55	31.2	34.9	4-4-2	4-6-4		85	49.2	22.3			0-10-2
56	31.8	34.5	4-4-2	4-6-4		86	49.8	21.9			
57	32.4	34.1	4-4-2	4-6-4	4-8-4	87	50.4	21.5		2-8-0	
58	33.0	33.7	4-6-2		4-8-4	88	51.0	21.1		2-8-0	
59	33.6	33.3	4-6-2		4-8-4	89	51.6	20.6		2-8-0	
60	34.2	32.8	4-6-2	2-8-4	4-8-4	90	52.2	20.2	2-10-0	2-6-0	
61	34.8	32.4	4-6-2	2-8-4	4-8-4	91	52.8	19.8	2-10-0	2-8-0	
62	35.4	32.0	4-6-2	2-8-4	4-8-4	92	53.4	19.4	2-10-0	2-8-0	
63	36.0	31.6	4-6-2	2-8-4	4-8-4	93	54.0	18.9	2-10-0	2-8-0	
64	36.6	31.2	4-6-2	2-8-4	4-8-4	94	54.6	18.5			
65	37.2	30.7	4-6-2	2-8-4	4-8-2	95	55.2	18.1			
66	37.8	30.3	2-10-4	2-8-4	4-8-2	96	55.8	17.7			
67	38.4	29.9	2-10-4	2-8-4	4-8-2	97	56.4	17.2			
68	39.0	29.5	2-10-4		4-8-2	98	57.0	16.8			
69	39.6	29.1	2-10-4	2-8-2	4-8-2	99	57.6	16.4			
70	40.2	28.6	2-10-4	2-8-2	4-8-2	100	58.2	16.0			

4 Cylinder Articulated Locomotives

67					79	49.2	22.3	2-8+8-4	
68	44.6	25.6	4-6+6-4		80	49.7	22.0	2-8+8-4	
69	45.0	25.3	4-6+6-4	2-6+6-4	81	50.1	21.7	2-8+8-4	
70	45.4	25.0	4-6+6-4	2-6+6-4	82	50.5	21.4	2-8+8-4	
71	45.8	24.7		2-6+6-4	83	51.0	21.1	2-8+8-4	2-6+6-2
72	46.2	24.4		2-6+6-4	84	51.4	20.8	2-8+8-4	
73	46.7	24.1		2-6+6-4	85	51.8	20.5	2-8+8-4	
74	47.1	23.8		2-6+6-4	86	52.2	20.2	2-8+8-4	2-8+8-2
75	47.5	23.5		2-6+6-4	87	52.6	19.9		2-8+8-2
76	48.0	23.2		2-6+6-4	88	53.0	19.6		2-8+8-2
77	48.4	22.9	2-8+6-4		89	53.4	19.3		2-8+8-2
78	48.8	22.6	2-8+8-4		90	53.9	19.0		2-8+8-2

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The choice between these two types of locomotives will generally be made on the basis of mechanical design in connection with the character of service and the profile and alinement of the road.

Typical Speed Curve Calculations—Steam Locomotives

Forms A and B are sample work sheets developed for computing the speed tractive effort curves of typical steam locomotives using superheated steam.

Form A is the simpler one and is intended to be used when design data are not available.

Form B is intended to be used when design data are available or when the maximum tractive effort is greater or less than 25 percent of the weight on drivers, that is, when it is necessary to adjust for the effective weight on drivers.

The driver tractive efforts per ton on drivers shown in column (c) Form A are based on cylinder tractive efforts less 20 lb. per ton on drivers, which is done to allow for the mechanical losses in the engine.

The cylinder tractive efforts shown in column (c) Form B are based on the cylinder horsepowers in column (g) which are obtained by means of an empirical formula.*

Example 4. Compare the speed tractive efforts of the 2–10–4 and 4–6 + 6–4 locomotives referred to in the previous example.

Solution—Use Form A and fill out the blank as shown on page 94. In the case of the 2–10–4 locomotive, for example, the horsepower per ton on drivers (K) is 5,400 ÷ 175 equals 30.8 hence the basic speed V_1 equals 0.396 × 30.8 or 12.2 m.p.h. (Item 9). Then in column b, $1.00\,V_1 = 12.2$, $1.25\,V_1 = 1.25 \times 12.2 = 15.25$, and so on up to 5 or 6 times V_1.

The driver tractive effort corresponding to zero speed is 500 lb. per ton on drivers or 500 × 175 equals a total of 87,500 lb. for the locomotive. The driver tractive effort corresponding to the speed $1.00\,V_1$ amounts to 480 lb. per ton on drivers times 175 equals

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* The empirical formula is

I.hp. per ton on drivers $= K\left(1 - e^{-0.75(U)^{3/2}}\right)$

Where K = normal hp. capacity per ton on drivers

$e = 2.718 +$ (base of Naperian logarithms)

$U = \frac{V}{V_1}$

V and V_1 = speeds in miles per hour

When $V = V_1$ I.hp. per ton on drivers $= K\left(1 - e^{-0.75}\right)$

$= K(1 - 0.472)$

$= 0.528K$

Also, when $V = V_1$ I.hp. per ton on drivers $= \frac{0.25 \times 2{,}000 \times V_1}{375} = \frac{500\,V_1}{375}$

or $\frac{500\,V_1}{375} = 0.528K$

hence $V_1 = 0.396K$ (See item (9), Forms A and B

Values in column (c), Form B, are found as follows.

When $V = 2V_1$ I.hp. per ton on drivers $= K\left(1 - e^{-0.75(2)^{3/2}}\right)$

$= K\left(1 - e^{-2.121}\right)$

$= 0.880\,K$

and the tractive effort per ton on drivers $= \frac{0.880K \times 375}{2 \times V_1}$

$= \frac{880K \times 375}{2 \times 0.396K}$

$= 417$ lb

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL STEAM LOCOMOTIVES
USING SUPERHEATED STEAM

FORM A

_____RAILROAD

Item

1. Type (Wheel Arrangement)_____
2. Weight on Drivers (Tons)_____
3. Weight of Engine_____
4. Weight of Tender_____
5. Total Weight_____

6. Ratio Item (2)/Item (3)_____

7. HP Per Ton on Drivers From Table 2 = K_____K'_____
8. HP Capacity of Loco. Item (2) x Item (7)_____
9. Basic Speed MPH = V_1 = .396 x K_____

Speed		Driver Tractive Effort		
V	MPH	Per Ton on Drivers	Total	
(a)	(b)	(c)	(d)	
0	0	500		
1.00xV_1		480		
1.25 "		473		
1.50 "		453		
1.75 "		427		
2.00 "		397		
2.25 "		369		
2.50 "		341		
2.75 "		314		
3.00 "		290		
3.50 "		250		
4.00 "		217		
4.50 "		190		
5.00 "		169		
6.00 "		138		
7.00 "		(115)		

With Booster

0		500		
1.00xV_1'		480		
1.25 "		473		
1.50 "		453		
1.75 "		427		
2.00 "		397		

Col. (b) = Col. (a) x Item (9) Col. (d) = Col. (c) x Item (2)

For Locomotives using Boosters add weight on Booster Axle to weight on Drivers, then K' equals Item (8)/Item (2) including weight on Booster Axle.

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL STEAM LOCOMOTIVES
USING SUPERHEATED STEAM

FORM B

_____ RAILROAD

Item		Actual	*Adjusted	(a) Booster
1.	Type (Wheel Arrangement)			
2.	Weight on Drivers (Tons)			
3.	Weight of Engine			
4.	Weight of Tender			
5.	Total Weight			
6.	Ratio Item (2)/Item (3)			

		Based on Table 2	Based on Design	See Note
7.	HP per Ton on Drivers = K		ø	K'
8.	HP Capacity of Locomotive			
9.	Basic Speed MPH = V_1 = .396 x K			V_1'

Speed V	Speed MPH	Cylinder Tractive Effort Per Ton on Drivers	Cylinder Tractive Effort Total	Engine Losses 20 Lb/Ton Act.Wt. on Drivers	Driver Tract. Effort Col(d)-Col(e)	Cylinder HP Per Ton on Drivers Adj.Wt.	Cylinder HP Total	Driver HP Total
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
0	0	500		0		0	0	0
1.00 x V_1		500				.528 x K		
1.25 "		493				.649 "		
1.50 "		473				.748 "		
1.75 "		447				.824 "		
2.00 "		417				.880 "		
2.25 "		389				.921 "		
2.50 "		361				.948 "		
2.75 "		334				.967 "		
3.00 "		310				.980 "		
3.50 "		270				.993 "		
4.00 "		237				.997 "		
4.50 "		210				.999 "		
5.00 "		189				1.000 "		
6.00 "		158				1.000 "		
7.00 "		(135)						

With Booster

0		500						
1.00 x V_1'		500						
1.25 "		493						
1.50 "		473						
1.75 "		447						
2.00 "		417						

*Adjusted weight on drivers (tons) = Rated tractive effort/500
øHP = K = Item (8)/Adjusted wt. on drivers
Col.(d) = Col.(c) x Item (2) Adjusted Col.(h) = Col.(g) x Item (2) Adjusted
Col.(f) = Col.(d) - Col.(e) Col.(i) = Col.(b) x Col.(f)/375

TE corresponding to 7xV_1 may be limited by cylinder capacity

(a) Note for locomotives with boosters weight on drivers equals rated tractive effort incl. booster/500. Determine K' and V_1' as above.

a total of 84,000 lb. The driver tractive efforts corresponding to other speeds are obtained in like manner by multiplying the tractive efforts shown in column (c) by the weight on drivers, 175 tons.

The speed tractive effort curves for the 2–10–4 and 4–6 + 6–4 locomotives resulting from the calculations are shown in Fig. 2.

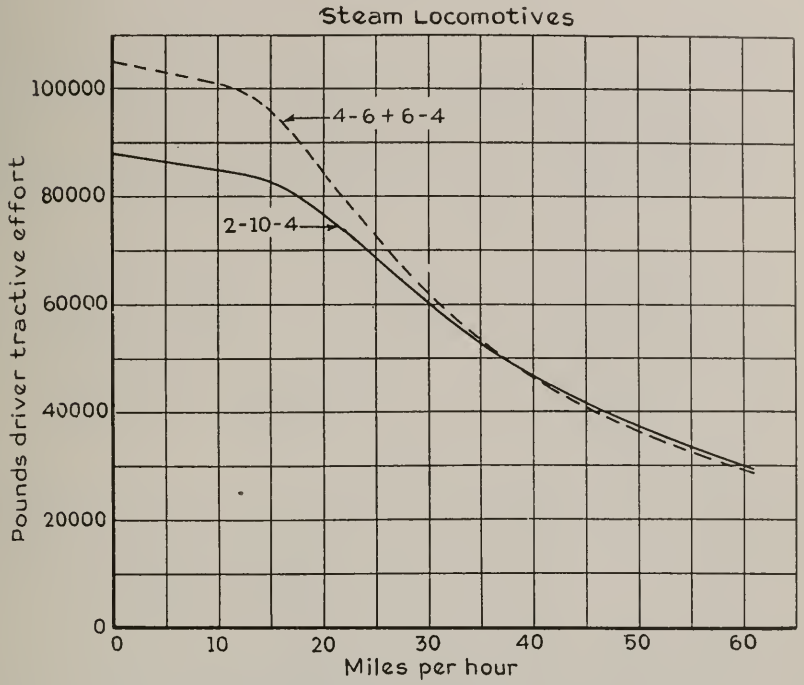


Fig. 2.—Typical Characteristic Curves, 2–10–4 and 4–6 + 6–4 Steam Locomotives.

Example 5. Determine the weight, horsepower and type of locomotive required to develop a driver tractive effort of 12,000 lb. at 95 m.p.h., assuming the allowable weight per driving axle is 65,000 lb.

Solution—The driver horsepower corresponding to 95 m.p.h. and 12,000 lb. amounts to $95 \times 12{,}000 \div 375$ or 3,040 hp., but the cylinder or boiler capacity of a locomotive capable of performing this service must be in excess of 3,040 hp. in order to overcome the mechanical losses in the engine.

The weight on drivers for a 4–6–4 locomotive based on 65,000 lb. per driving axle will be $3 \times 65{,}000$, or 97.5 tons. The maximum horsepower shown in Table 2 for 4–6–4 locomotives is 36.2 hp. per ton on drivers which is equal to 3,530 hp. total based on 97.5 tons on drivers. Try this locomotive.

On Form A, note that $V_1 = 0.396 \times K = 0.396 \times 36.2$ equals 14.34 m.p.h. Note, also, the maximum speed shown is $7.00\,V_1$ which corresponds to 7.0×14.34 equals 100.38 m.p.h.

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL STEAM LOCOMOTIVES
USING SUPERHEATED STEAM

FORM A

Sample RAILROAD

Item		2-10-4	4-6+6-4
1.	Type (Wheel Arrangement)	2-10-4	4-6+6-4
2.	Weight on Drivers (Tons)	175	210
3.	Weight of Engine	269	309
4.	Weight of Tender	201	201
5.	Total Weight	470	510
6.	Ratio Item (2)/Item (3)	.65	.68
7.	HP Per Ton on Drivers From Table 2 = K	30.8	K' 25.7
8.	HP Capacity of Loco. Item (2) x Item (7)	5400	5400
9.	Basic Speed MPH = V_1 = .396 x K	12.2	10.2

Speed		Driver Tractive Effort (2-10-4)		Miles per Hour	Driver Tractive Effort (4-6+6-4)	
V	MPH	Per Ton on Drivers	Total		Total	
(a)	(b)	(c)	(d)			
0	0	500	87,500	0	105,000	
1.00xV_1	12.20	480	84,000	10.20	100,800	
1.25 "	15.25	473	82,780	12.75	99,330	
1.50 "	18.30	453	79,280	15.30	95,130	
1.75 "	21.35	427	74,730	17.85	89,670	
2.00 "	24.40	397	69,480	20.40	83,370	
2.25 "	27.45	369	64,580	22.95	77,490	
2.50 "	30.50	341	59,680	25.50	71,610	
2.75 "	33.55	314	54,950	28.05	65,940	
3.00 "	36.60	290	50,750	30.60	60,900	
3.50 "	42.70	250	43,750	35.70	52,500	
4.00 "	48.80	217	37,975	40.80	45,570	
4.50 "	54.90	190	33,250	45.90	39,900	
5.00 "	61.00	169	29,580	51.00	35,490	
6.00 "		138		61.20	28,980	
7.00 "		(115)				

With Booster

0		500		
1.00xV_1'		480		
1.25 "		473		
1.50 "		453		
1.75 "		427		
2.00 "		397		

Col. (b) = Col. (a) x Item (9) Col. (d) = Col. (c) x Item (2)

For Locomotives using Boosters add weight on Booster Axle to weight on Drivers, then K' equals Item (8)/Item (2) including weight on Booster Axle.

The driver tractive effort corresponding to $7.0\,V_1$ may amount to 115 lb. per ton on drivers, or a total of 11,213 lb. (97.5×115).

Adjusting for 95 m.p.h. ($100.38 \times 11{,}213 \div 95$), the tractive effort corresponding to 95 m.p.h. equals 11,850 lb. or about the tractive effort required.

It is, therefore, practical to assume a 4–6–4 locomotive and base preliminary studies on the following weights:

Weight of engine $97.5 \div 0.52$	189 tons
Weight of engine and tender $97.5 \div 0.294$	332 tons
Weight of tender	143 tons

It may develop from the preliminary studies that the service requires a tender of larger capacity, or that it is advisable to limit the maximum tractive effort to 44,000 lb. instead of 48,750 lb. For example, the final design may be as follows, in which case it would be necessary to use Form B as indicated on page 96, because the tractive effort 44,000 lb. is less (or more) than 25 percent of the weight on drivers.

Type	4–6–4
Weight on drivers	195,000 lb.
Weight of engine	371,000 lb.
Weight of tender	330,000 lb.
Total weight	701,000 lb.
Boiler pressure	285 lb. per sq. in.
Diameter of drivers	80 in.
Cylinders diameter times stroke	22 x 30 in.
Tractive effort engine	44,000 lb.
Tractive effort including booster	54,000 lb.

The tractive effort based on design $= \dfrac{d^2 \times S \times P \times 0.85}{D}$

Where d = diameter of cylinders in inches
S = stroke in inches
P = boiler pressure pounds per square inch
D = diameter of drivers in inches
0.85 = constant (ratio of mean effective pressure to boiler pressure)

Thus, if the cylinders were bored out an inch and the boiler pressure increased about 5 lb., the tractive effort would be increased from 44,000 lb. to 48,750 lb., or 500 lb. per ton on drivers, in which case it would be simpler to use Form A.

PERFORMANCE AND FUEL CONSUMPTION

The chief purpose of speed tractive effort and horsepower curves is to estimate the performance and the fuel or energy consumption in service. For quick estimates the amount of work done or the net energy in foot-pounds required to move a train of given weight over a known profile can be easily obtained by multiplying the distance traveled in feet by the train resistance in pounds per ton including the resistance due to grades and curves, times the weight of train and locomotive. Down grade sections where the grade effect exceeds the train resistance including the resistance due to curves, are neglected in these calculations because the excess energy due to the grade is generally not recovered but wasted in the brakes.

Such estimates are independent of the type of motive power used and do not include any allowances for acceleration and braking or other losses which are inherent in various types of motive power. It is a convenient way to compare the energy or fuel consumption by various routes, provided the consumption by one route is known.

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL STEAM LOCOMOTIVES
USING SUPERHEATED STEAM

FORM B

SAMPLE RAILROAD

Item

1. Type (Wheel Arrangement) 4-6-4

	Actual	*Adjusted	(a) Booster
2. Weight on Drivers (Tons)	97.5	88.0	108.0
3. Weight of Engine	185.0		
4. Weight of Tender	165.0		
5. Total Weight	350.0		
6. Ratio Item (2)/Item (3)			

	Based on Table 2	Based on Design	See Note
7. HP per Ton on Drivers = K	36.0	ø 39.3	K' 32.4
8. HP Capacity of Locomotive	3500		
9. Basic Speed MPH = V_1 = .396 x K		15.75	V_1'

Speed V	Speed MPH	Cylinder Tractive Effort Per Ton on Drivers	Cylinder Tractive Effort Total	Engine Losses 20 Lb/Ton Act.Wt. on Drivers	Driver Tract. Effort Col(d)-Col(e)	Cylinder HP Per Ton on Drivers Adj.Wt.	Cylinder HP Total	Driver HP Total
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
0	0	500	44,000	0	44,000	0	0	0
1.00 x V_1	15.75	500	44,000	1950	42,050	.528 x K	1848	1766
1.25 "	19.70	493	43,300	1950	41,350	.649 "	2272	2171
1.50 "	23.63	473	41,600	1950	39,650	.748 "	2618	2500
1.75 "	27.56	447	39,350	1950	37,400	.824 "	2884	2750
2.00 "	31.50	417	36,700	1950	34,750	.880 "	3080	2920
2.25 "	35.44	389	34,250	1950	32,300	.921 "	3224	3055
2.50 "	39.38	361	31,800	1950	29,850	.948 "	3319	3135
2.75 "	43.32	334	29,400	1950	27,450	.967 "	3385	3175
3.00 "	47.25	310	27,300	1950	25,350	.980 "	3430	3195
3.50 "	55.13	270	23,800	1950	21,850	.993 "	3476	3205
4.00 "	63.00	237	20,900	1950	18,950	.997 "	3490	3185
4.50 "	70.88	210	18,500	1950	16,550	.999 "	3497	3125
5.00 "	78.75	189	16,650	1950	14,700	1.000 "	3500	3085
6.00 "	94.50	158	13,900	1950	11,950	1.000 "	3500	3010
7.00 "		(135)						

With Booster

0	0	500	54,000	0	54,000			
1.00 x V_1'	12.84	500	54,000	2160	51,840			
1.25 "	16.05	493	53,200	2160	51,040			
1.50 "	19.26	473	51,100	2160	48,940			
1.75 "		447	48,300	2160	46,140			
2.00 "	25.68	417	45,000	2160	42,840			

*Adjusted weight on drivers (tons) = Rated tractive effort/500

øHP = K = Item (8)/Adjusted wt. on drivers

Col.(d) = Col.(c) x Item (2) Adjusted Col.(h) = Col.(g) x Item (2) Adjusted

Col.(f) = Col.(d) - Col.(e) Col.(i) = Col.(b) x Col.(f)/375

TE corresponding to 7xV_1 may be limited by cylinder capacity

(a) Note for locomotives with boosters weight on drivers equals rated tractive effort incl. booster/500. Determine K' and V_1' as above.

To estimate the fuel or energy consumption more accurately it is necessary to calculate the performance of the particular type of locomotive proposed, based on its speed tractive effort curves, the type and weight of train and the profile of the district. The calculations are known as speed-time-distance calculations which constitute a step-by-step process that approximates the results obtained from dynamometer-car tests. From these calculations the input (indicated horsepower-hours for steam, or kw.-hr. output of substations for electric) can be computed. In the case of steam locomotives the corresponding boiler output (evaporation) and fuel consumption can be estimated, based

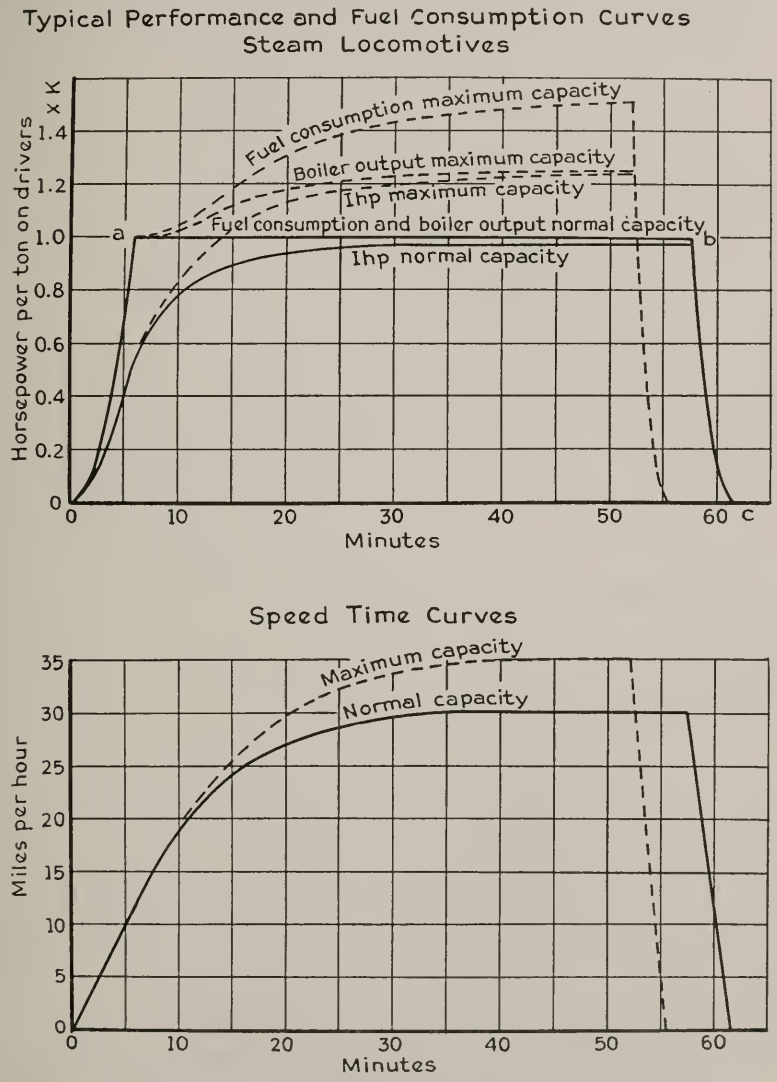


Fig. 3.—Typical Performance, Fuel Consumption and Speed-Time Curves for Steam Locomotives.

upon the water rate, boiler efficiency and quality of fuel. A discussion of a method for making these calculations follows.

The upper chart of Fig. 3 shows the indicated horsepower input to the locomotive, the boiler output and the fuel consumption based on the speed-time curves in the lower chart. The solid lines of the chart are based on normal capacity and the dotted lines on the overload capacity, or 1 1/3 times normal.

For normal output it is assumed that the fuel consumption and boiler output is maintained constant, hence they can be represented by the horizontal line (a-b) corresponding to $1.0 \times K$. During the starting period (o-a) the normal output of the boiler cannot be used until a speed equal to V_1 has been reached because the cylinders will only allow a limited amount of steam to flow. In other words, the steam consumption de-

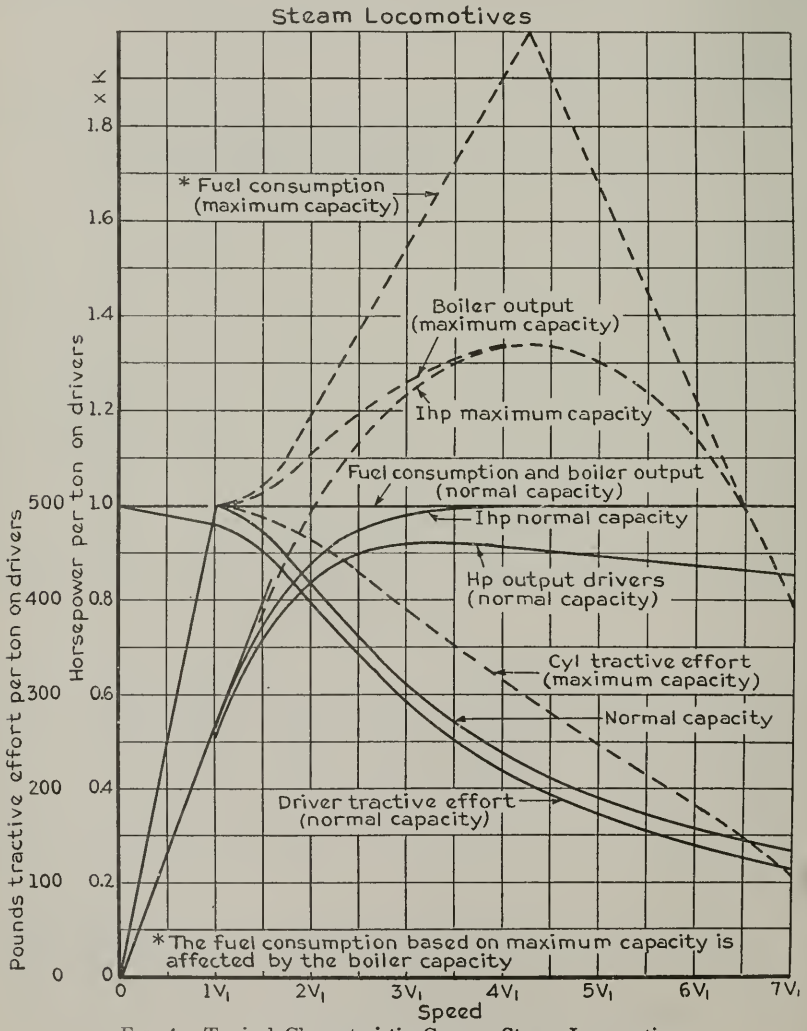


Fig. 4.—Typical Characteristic Curves, Steam Locomotives.

pends upon the number of revolutions made by the drivers, which is proportional to the distance traveled in reaching the speed corresponding to V_1. Since the distance traveled is proportional to the square of the time, the boiler output during this period can be represented by a curve (o-a) which encloses an area equal to one-third of the product of the base times the altitude. That is, the average boiler output during this period amounts to one-third the normal output.

Theoretically, the fuel consumption during these periods would be less than one-third of the normal consumption, but for simplicity it is assumed that the fuel consumption is proportional to the boiler output. Thus the fuel consumption and the boiler output for normal operation are represented by the area o-a-b-c. The indicated horsepower developed is represented by the smooth curve shown by the solid line, and the indicated horsepower-hours by the area under the curve.

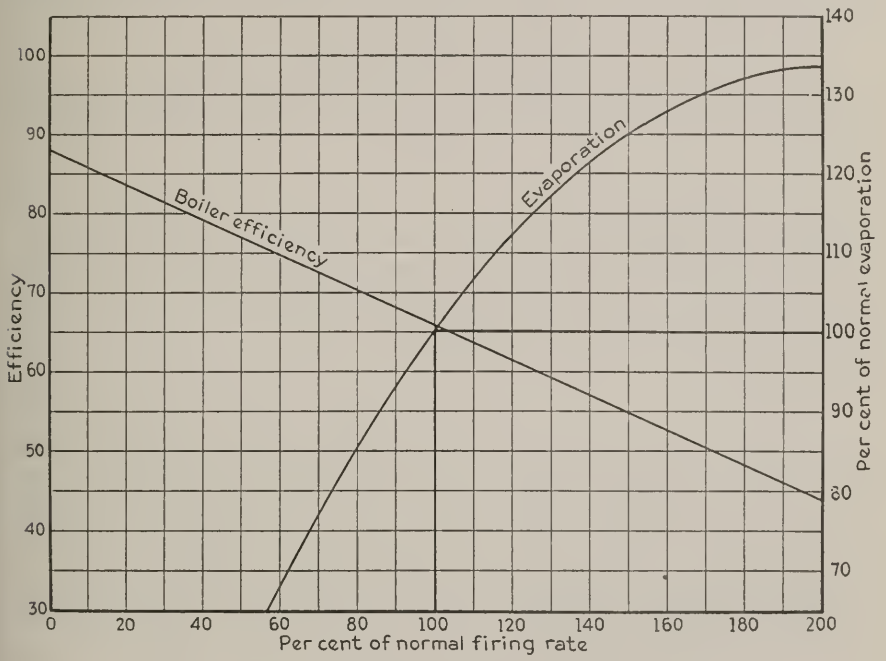


Fig. 5.—Typical Characteristics, Steam Locomotive Boilers.

The dotted speed-time curve is based on the overload characteristics of the locomotive shown dotted in Fig. 4. In this case the boiler output and fuel consumption are not constant, but depend upon the indicated horsepower. The boiler output does not increase as fast as the indicated horsepower because the steam economy of the engine improves as the speed increases, but the fuel consumption increases faster than the indicated horsepower because the boiler efficiency is lower at the higher boiler outputs as indicated in Fig. 5. For example, it is assumed that the normal rate of firing is equal to one-half the firing rate that corresponds to maximum evaporation. On this basis the maximum boiler output is only a third greater than normal, whereas the firing rate is double.

In applying the fuel-consumption curve of Fig. 4 to the speed-time curve of Fig. 3 the maximum speed of 35 m.p.h. corresponds to about $2.9 \times V_1$, hence the fuel consumption is approximately 1.51 $\times$ normal as shown on both charts. Corresponding points

on the boiler output and indicated horsepower curves are 1.25 and 1.21, respectively. Other points on the curves can be found in like manner. In the case of this particular speed-time curve the boiler is not forced to its maximum capacity.

A comparison between normal and overload operation can be made by measuring the areas under these curves.

Comparison of Performance, 25-Mile Run

	Normal	*Overload*	*Ratio*
Maximum speed	30.0	35.4	1.180
Average speed	24.35	27.00	1.109
Hp. hrs. output at drivers	$0.735 \times K$	$0.847 \times K$	1.101
I. Hp. hrs.	$0.811 \times K$	$0.889 \times K$	1.096
Hp. hrs. output boiler	$0.944 \times K$	$0.975 \times K$	1.064
Fuel consumption	$0.944 \times K$	$1.108 \times K$	*1.210

K equals the normal horsepower per ton on drivers.

* This ratio depends upon the relation between cylinder and boiler capacities.

The chief reason for discussing overload conditions is for the purpose of analyzing test results. For performance estimates it is seldom necessary to resort to this extra refinement.

Water Consumption

The amount of steam required for a given run will be equal to the product of the horsepower-hours output of the boiler times the steam factor (pounds of steam per horsepower-hour). When the steam factor is known the heat units per pound of steam based on the pressure and degrees of superheat can be obtained from steam tables. It can be assumed that it requires the transfer of about 1300 B.t.u. to produce one pound of steam for modern steam locomotives.

Fuel Consumption

If there are ten times as many B.t.u. in a pound of coal as in a pound of steam, then one pound of coal would evaporate ten pounds of water, based on 100 per cent boiler efficiency. The boiler efficiency from Fig. 5, corresponding to the normal firing rate, is 66 per cent. On this basis a pound of 13,000-B.t.u. coal would only evaporate 6.6 lb. of water. The data on which the chart Fig. 5 is based are rather old and the efficiencies shown are considered low for modern locomotives. Accounts of recent tests indicate that higher boiler efficiencies are obtained and that the evaporations shown in the table are feasible for comparative purposes. In practice it is customary to include safe margins to cover contingencies.

Approximate Pounds of Water Evaporated Per Pound of Coal of Various Quality Based on Normal Firing Rates

Quality	*Without Feedwater Heaters*	*With Feedwater Heaters*
15,000 B.t.u. per lb.	8.5	9.2
14,000 " " "	7.9	8.5
13,000 " " "	7.3	7.9
12,000 " " "	6.6	7.1
11,000 " " "	*6.1	*6.6
10,000 " " "	*5.6	*6.0
9,000 " " "	*5.0	*5.4
8,000 " " "	*4.3	*4.6

* Low fuel quality affects the horsepower capacity and the weight of steam locomotives, consequently it will be necessary to adjust the characteristic curves and the performance when low quality fuels are considered.

Example: In order to show the application of this table assume the speed-time and fuel consumption curves, which are shown in Fig. 3 and compared in the table on page 100, are based on a locomotive rated 4,000 hp. and weighing 133 tons on drivers. Find the water and coal consumption based on 13,000 B.t.u. coal.

From the table on page 100, the horsepower-hours output of the boiler amounts to $0.944 \times K$. The constant K represents the rated horsepower capacity per ton on drivers or $4{,}000 \div 133$ equals 30, hence the boiler output equals $0.944 \times 30 \times 133$, or 3,776 hp. hr. Assume the steam factor of the locomotive is 18 lb. per hp. hr., then the pounds of water consumed will be $3{,}776 \times 18$, or 68,000 lb.

The amount of water evaporated per pound of 13,000 B.t.u. coal is found from the above table (7.9 lb.) based on using feedwater heaters, hence the amount of coal consumed amounts to $68{,}000 \div 7.9$ or 8,600 lb. or 4.3 tons.

ELECTRIC LOCOMOTIVES

Systems of Electrification

There are two general systems of electrification, namely, the Direct Current and the Alternating Current Systems.

Types of Electric Locomotives

In all, there are four types of electric locomotives: (a) Direct-current locomotives, (b) single-phase alternating-current locomotives, (c) split-phase induction-motor locomotives and (d) single-phase motor-generator locomotives. The last three types have been developed for the alternating-current system and are, therefore, classed as alternating current locomotives. The same basic principles apply to all four types, but their inherent characteristics are different which makes it necessary to develop special work sheets for computing the speed curves of each type.

Difference Between Steam and Electric Locomotives

Locomotive Capacity. From a performance standpoint the chief difference between steam and electric locomotives is due to the fact that the output of steam locomotives is limited by the capacity of the boiler to supply steam, whereas electric locomotives draw their power from an outside source which has a relatively unlimited capacity.

Adhesion Limit—On account of the uniform tractive effort and overload capacities of electric locomotives, the adhesion limit for electric locomotives is higher than it is for steam locomotives, but in most instances it is assumed the same as for steam locomotives (25 percent of the weight on drivers). The equipment, however, is generally designed with sufficient overload capacity to develop tractive efforts up to 30 percent of the weight on drivers when rail conditions permit.

Locomotive Classifications. The mechanical design and construction of steam and electric locomotives are naturally different because the methods used for applying power are different. For this reason the wheel arrangements in the case of electric locomotives are more numerous and varied than in the case of steam locomotives. In fact it is necessary to employ a different method from the one adopted for classifying steam locomotives in order to identify the driving from non-driving axles.

In the electric system letters are used to indicate the number of driving axles the first, second, third, etc. letters of the alphabet A, B, C, etc. indicate one, two, three driving axles and numerals represent idle axles. Thus 2–D–2 indicates two guiding axles, four driving axles and two trailing axles, and corresponds to 4–8–4 in the steam classification.

Horsepower Rating of Electric Locomotives. The horsepower rating of electric locomotives is an arbitrary rating which is determined by the heating of the motors in accordance with rules prescribed by the American Institute of Electrical Engineers. In actual cases it is customary for the manufactures to furnish characteristic curves of their locomotives and to specify the speeds and tractive efforts corresponding to the one-hour and continuous ratings.

In preliminary studies for the purpose of comparing performances between steam and electric locomotives it is important to be able to calculate typical characteristic curves of electric locomotives, based on their ratings or independent of their ratings, which will duplicate the performance estimated for steam locomotives.

Typical Speed Tractive-Effort Curves of Electric Locomotives

Typical speed tractive effort curves of direct current and single-phase alternating-current locomotive can be calculated by the following empirical equations.

Direct Current Locomotives

$$*\frac{T'}{T''} = \frac{(V'')^3}{V'} \text{ or } \frac{V'}{V''} = \frac{(T'')^{1/3}}{T'}$$

That is, the tractive efforts are approximately inversely proportional to the cube of the speeds.

Single Phase Alternating Current Locomotives

$$\frac{T'}{T''} = \frac{(V'')^{5/3}}{V'} \text{ or } \frac{V'}{V''} = \frac{(T'')^{3/5}}{T'}$$

In other words, the tractive efforts of single phase alternating current locomotives, based on constant voltage, are approximately inversely proportional to the five-thirds power of the speed.

Forms C and D are sample work sheets, based on these formulas, designed to facilitate the calculation of speed-tractive effort and horsepower output of direct-current and single-phase alternating-current locomotives as well as the kilowatt output of substations. A few examples will illustrate their application and emphasize some of the differences between steam and electric locomotives.

Direct Current Locomotives

Example 6. Given the weight on drivers and the continuous rating of the locomotive or any point on the characteristic curve find V_1 and calculate the curve assuming the following, locomotive 2 — B + B + B + B — 2 450/576 having a continuous rating of 3,350 hp. at a speed of 21.6 m.p.h. on shunted field.

Weight on drivers 450,000 lb. ..... 225 tons
Weight of locomotive 576,000 lb. ..... 288 tons
Number of motors (4 × 2)

Solution:—

$$\text{Since } Hp = \frac{T.E. \times M.P.H.}{375}$$

$$T.E. = \frac{375 \times Hp.}{M.P.H.} = \frac{375 \times 3{,}350}{21.6} = 58{,}200 \text{ lb.}$$

$T.E.$ per ton on drivers $= 58{,}200 \div 225 = 258.5$ lb.

* Transactions A.I.E.E. Vol. XXXIII (1914), p. 1710.

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL ELECTRIC LOCOMOTIVES
DIRECT CURRENT

FORM C

_____RAILROAD

ITEM

1. Type (Wheel Arrangement)_____
2. Weight on Drivers (Tons)_____
3. Weight of Locomotive Total_____
4. Number of Motors_____

Locomotive Ratings	1-Hour	Continuous
5. Horsepower		
6. Speed (90% voltage)		
7. Tractive Effort		

Speed		Driver Tractive Effort		Locomotive Output		Substation Output	
V	Miles per Hour	Lbs per Ton on Drivers	Total	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
0	0			0	0	★	--
.94 x V_1		600		1.504 x V_1		1.460 x V_1	
1.00 "		500		1.333 "		1.270 "	
1.10 "		376		1.103 "		1.023 "	
1.20 "		289		.925 "		.844 "	
1.30 "		228		.790 "		.708 "	
1.40 "		182		.680 "		.605 "	
1.50 "		148		.592 "		.521 "	
1.60 "		122		.521 "		.457 "	
1.80 "		86		.413 "		.361 "	
2.00 "		63		.336 "		.295 "	
2.20 "		47		.276 "		.247 "	
2.40 "		36		.232 "		.213 "	
2.60 "		28		.194 "		.187 "	
Shunted Field							
1.32 x V_1		376		1.324 x V_1		1.250 x V_1	
1.44 "		289		1.110 "		1.031 "	
1.56 "		228		.948 "		.866 "	
1.68 "		182		.816 "		.734 "	
1.80 "		148		.710 "		.632 "	
1.92 "		122		.625 "		.552 "	
2.16 "		86		.496 "		.435 "	
2.40 "		63		.403 "		.352 "	
2.64 "		47		.331 "		.291 "	

★Substation Output During Acceleration

Rheostatic		Series Parallel		Three Speed	
Speed	KW Output	Speed	KW Output	Speed	KW Output
From 0 to 1.0V_1	1.270 x V_1	From 0 to 1/2V_1	.612 x V_1	From 0 to 1/3V_1	.404 x V_1
		" 1/2V " 1.0V_1	1.270 "	" 1/3V_1 " 2/3V_1	.833 "
				" 2/3V_1 " 1.0V_1	1.270 "

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL ELECTRIC LOCOMOTIVES
SINGLE PHASE ALTERNATING CURRENT

FORM D

_____ RAILROAD

ITEM

1. Type (Wheel Arrangement)_____
2. Weight on Drivers (Tons)_____
3. Weight of Locomotive Total_____
4. Number of Motors_____

Locomotive Ratings	1-Hour	Continuous
5. Horsepower		
6. Speed		
7. Tractive Effort		

Speed		Driver Tractive Effort		Locomotive Output		Substation Output	
V	Miles per Hour	Lbs per Ton on Drivers	Total ♦	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total ★
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
0	0	500		0	0	0	0
1.00 x V_1		500		1.333 x V_1		1.333 x V_1	
1.10 "		426		1.250 "		1.250 "	
1.20 "		369		1.181 "		1.181 "	
1.30 "		323		1.120 "		1.120 "	
1.40 "		285		1.065 "		1.065 "	
1.50 "		254		1.016 "		1.016 "	
1.60 "		228		.973 "		.973 "	
1.80 "		188		.902 "		.902 "	
2.00 "		157		.837 "		.837 "	
2.20 "		135		.792 "		.792 "	
2.40 "		116		.742 "		.742 "	
2.60 "		102		.707 "		.707 "	
2.80 "		90		.671 "		.671 "	
3.00 "		80		.640 "		.640 "	

Supplementary Characteristic Curves

♦Driver Tractive Effort	Miles per Hour				KW Substation Output				
	V'	V"			Col★	V'	V"		
CONSTANT OUTPUT									
MPH									
TE									

On Form C, Col. (c), under shunted field find the nearest figures to 258.5 (289 corresponding to $1.44 \times V_1$ and 228 corresponding to $1.56 \times V_1$). By interpolation the speed corresponding to 258.5 is found to be halfway between 1.44 and 1.56 or $1.50V_1$. Hence V_1 equals $21.6 \div 1.5$ or 14.4 m.p.h., based on full substation voltage. For estimating performance it is usually assumed that the average trolley voltage amounts to 90 percent of the substation voltage hence the speed tractive effort calculations would be based on 90 percent of 14.4 or 13.0 m.p.h.

The driver tractive effort corresponding to 13.0 m.p.h. ($1 \times V_1$*) equals 500×225 or 112,500 lb., the output of the locomotive equals $1.333 \times 13.0 \times 225$ or 3,900 hp. and the substation output equals $1.270 \times 13.0 \times 225$ or 3,715 kw., equals $3,715 \div 746$ or 4,980 hp.

Example 7. Develop the characteristics of direct-current and single-phase alternating-current locomotives for comparison with a proposed 4–8–6 steam locomotive rated at 5,000 hp.

Solution: From Table 1 it will be found that the weight on drivers for a 4–8–6 steam locomotive will constitute 50 to 57.2 percent of the weight of the engine. Assume it is 50 percent; then from Table 2 the indicated horsepower per ton on drivers corresponding to 50 percent is found to be 37.1, hence the estimated weight on drivers for the steam locomotive will be $5,000 \div 37.1$, equals 135 tons and the total weight of engine and tender will be $135 \div 28.2$, equals 480 tons.

Using Form A compute the speed tractive effort and find the tractive effort corresponding to any desired speed, say 90 m.p.h., assuming the locomotive is intended for high speed passenger service. By plotting the calculated curve the tractive effort is found to be approximately 18,230 lb. at 90 m.p.h. Assume the electric locomotives will only have to develop 18,000 lb. at 90 m.p.h. on account of the omission of the tender.

The next step is to calculate the typical characteristic curves of each type of electric locomotive based on 18,000 lb. and 90 m.p.h. as explained in Example 6. Plot the curves for comparison with the steam locomotive. (See Fig. 6).

The next step is to estimate the weight of comparable electric locomotives, (a) based on direct current, and (b) based on single-phase alternating current. The weights of electric locomotives depend upon the type of construction employed, hence it is often important to consider two or more basic designs when making comparisons with steam locomotives.

(a) Direct Current Locomotives

For electrical reasons direct-current locomotives are designed for multiples of four and six motors. In the case of this example if the locomotive is designed for four motors, then it is limited to the same weight on drivers as the steam locomotive, because they each have four pairs of drivers.

If a 6-motor type of construction is considered the weight on drivers for the electric can be 50 percent more than for the proposed steam locomotive. Likewise, a number of other wheel combinations can be considered, for example multiple unit types consisting of two 4-motor units, etc.

The total weight, and weight on drivers, for these types of construction may vary over a wide range, but theoretically the speed tractive effort curve plotted in Fig. 7

* Under favorable track conditions it is possible for the locomotive to exert a tractive effort of 600 lb. per ton on drivers (30 per cent of the weight on drivers) or 135,000 lb. at 12.22 m.p.h. (0.94×13.0). In this case the substation output amounts to 5,720 hp., which is equal to 1.70 times the rated capacity of the locomotive or 70 percent overload.

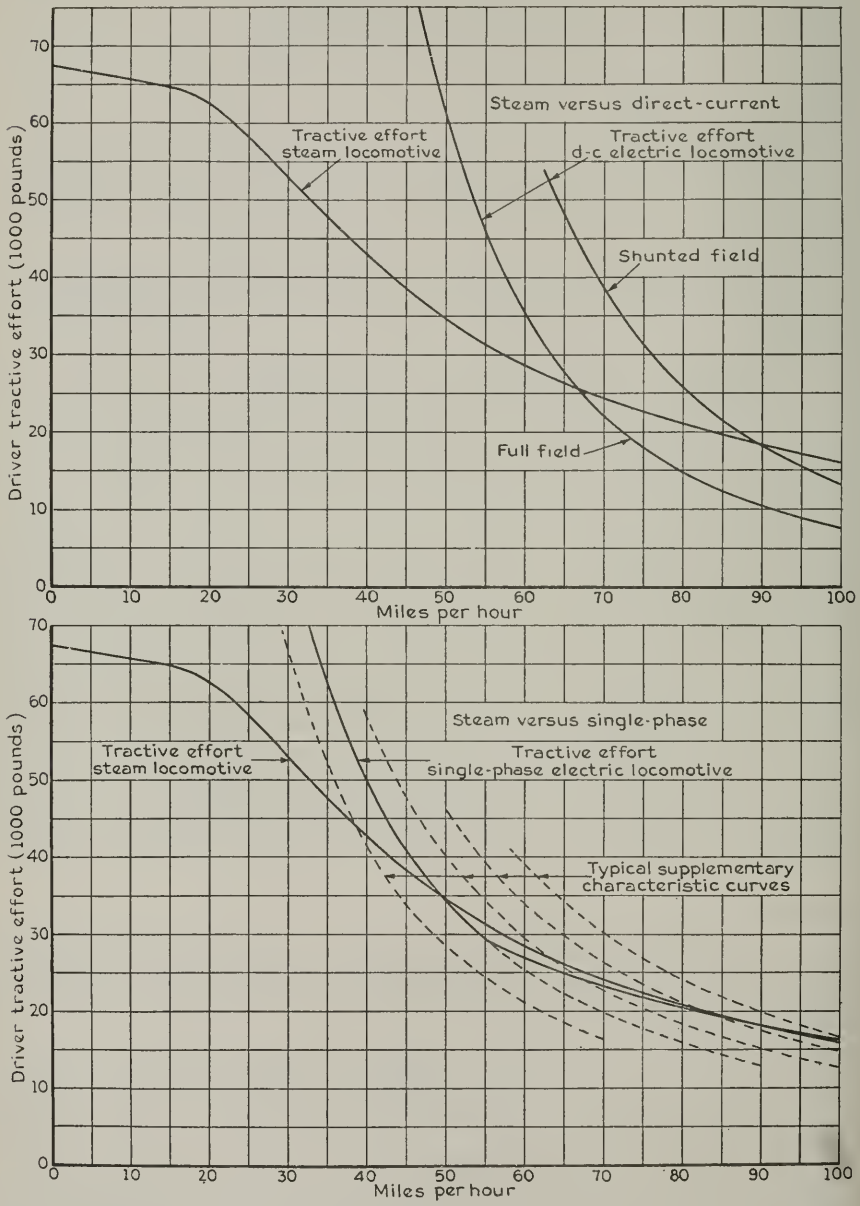


Fig. 6.—Comparative Speed—Tractive Effort Curves, Steam and Electric Locomotives.

will be the same for all except as regards maximum tractive efforts. In this connection it is important to note that generally the only safeguard there is against excessive overloads for electric locomotives is the slipping point of the wheels which, for this purpose, is usually assumed to be equal to 30 percent of the weight on drivers, or 600 lb. per ton on drivers. Under these conditions the locomotive output $1.504 \times V_1$ horsepower per ton on drivers shown in col. (e), Form C, opposite $0.94 \times V_1$ is a measure of the maximum output of the locomotive.

If the maximum output is to be limited to 2½ times the normal output then the normal output will be approximately $1.504 \times V_1 \div 2.5$, or $0.602 \times V_1$ hp. per ton on drivers, which corresponds with about 116 lb. tractive effort per ton on drivers, and to a speed $1.94 \times V_1$ in the shunted field position. On this basis the weight on drivers for a locomotive designed for 18,000 lb. tractive effort at 90 m.p.h. should not exceed $18{,}000 \div 116$, or 150 to 155 tons. The total weight for preliminary estimates can be taken at 30 to 35 percent more than the weight on drivers, or 200 to 210 tons, if guiding and trailing trucks are required.

The speed corresponding to the maximum tractive effort $1 \times V_1$ will be $90 \div 1.94$ or 46.3 m.p.h. The output of the locomotive and substations can now be calculated by filling out Form C.

After the performances of steam and electric locomotives have been compared on the basis of these characteristics, the locomotive builders will be able to make whatever adjustments are necessary and determine the horsepower rating of the locomotive.

When comparing freight performances the procedure is the same except that it is customary to limit the maximum output to about 1.5 times the normal output or less. In some cases it has been practical to use the same type of construction for both passenger and freight service by simply changing the motor gearing. Thus, if it were desired to duplicate the performance of the 4–8–6 locomotive in freight service based on 45 m.p.h. and 38,500 lb. tractive effort, the electric locomotive would be geared to give about 38,000 lb. at 45 m.p.h., in which case it would exert its maximum tractive effort 77,500 lb. (based on 155 tons and 500 lb. per ton on drivers) at a speed of 29.5 m.p.h. found by substituting in the formula.*

$$\frac{V'}{V''} = \frac{(T'')^{1/3}}{T'} \quad \text{or} \quad \frac{45}{1.2 \times V_1} = \left(\frac{77{,}500}{38{,}000}\right)^{1/3}$$

$$1.2 \times V_1 = \frac{45}{1.27} = 35.4$$

$$V_1 = 29.5 \text{ m.p.h.}$$

(b) Single Phase Alternating Current Locomotives

The theory in regard to single phase alternating current locomotives is the same as for direct current locomotives except that it is practical to provide high voltage taps on the transformer in order to maintain constant output at the higher speeds. For this

* Dividing 45 by 1.20 gives the speed in full-field connection corresponding to 45 m.p.h. in the shunted-field connection. It can be shown in the case of direct-current locomotives that the ratio of freight gearing to passenger gearing will be inversely proportional to the two-thirds power of the V_1s, that is,

$$\frac{\text{Freight gearing}}{\text{Passenger gearing}} = \left(\frac{46.3}{29.5}\right)^{3/2}$$

$$\text{Freight gearing} = 1.97 \times \text{passenger gearing}$$

Hence, it is often necessary to check the permissible maximum safe operating speeds in freight service

$$\text{Gear ratio} = \frac{\text{Number of teeth in the gear}}{\text{Number of teeth in the pinion}}$$

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL ELECTRIC LOCOMOTIVES
DIRECT CURRENT

FORM C

Sample RAILROAD

ITEM

1. Type (Wheel Arrangement)
2. Weight on Drivers (Tons) 150
3. Weight of Locomotive Total 210
4. Number of Motors

Locomotive Ratings	1-Hour	Continuous
5. Horsepower		
6. Speed (90% voltage)		
7. Tractive Effort		

Speed		Driver Tractive Effort		Locomotive Output		Substation Output	
V	Miles per Hour	Lbs per Ton on Drivers	Total	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
0	0			0	0	★	--
.94 x V_1		600		1.504 x V_1		1.460 x V_1	
1.00 "	46.60	500	75,000	1.333 "	9331	1.270 "	8890
1.10 "	51.26	376	56,400	1.103 "	7721	1.023 "	7161
1.20 "	55.92	289	43,350	.925 "	6475	.844 "	5908
1.30 "	60.58	228	34,200	.790 "	5530	.708 "	4956
1.40 "	65.24	182	27,300	.680 "	4760	.605 "	4235
1.50 "	69.90	148	22,200	.592 "	4144	.521 "	3647
1.60 "	74.56	122	18,300	.521 "	3647	.457 "	3199
1.80 "	83.88	86	12,900	.413 "	2891	.361 "	2527
2.00 "	93.20	63	9,450	.336 "	2352	.295 "	2065
2.20 "	102.52	47	7,050	.276 "	1932	.247 "	1729
2.40 "		36		.232 "		.213 "	
2.60 "		28		.194 "		.187 "	

Shunted Field

1.32 x V_1	61.51	376	56400	1.324 x V_1	9268	1.250 x V_1	8750
1.44 "	67.10	289	43350	1.110 "	7770	1.031 "	7217
1.56 "	72.70	228	34200	.948 "	6636	.866 "	6062
1.68 "	78.29	182	27300	.816 "	5712	.734 "	5138
1.80 "	83.88	148	22200	.710 "	4970	.632 "	4424
1.92 "	89.47	122	18300	.625 "	4375	.552 "	3864
2.16 "	100.66	86	12900	.496 "	3472	.435 "	3045
2.40 "		63		.403 "		.352 "	
2.64 "		47		.331 "		.291 "	

★Substation Output During Acceleration

Rheostatic		Series Parallel		Three Speed	
Speed	KW Output	Speed	KW Output	Speed	KW Output
From 0 to 1.0V_1	1.270 x V_1	From 0 to 1/2V_1	.612 x V_1	From 0 to 1/3V_1	.404 x V_1
		" 1/2V " 1.0V_1	1.270 "	" 1/3V_1 " 2/3V_1	.833 "
				" 2/3V_1 " 1.0V_1	1.270 "

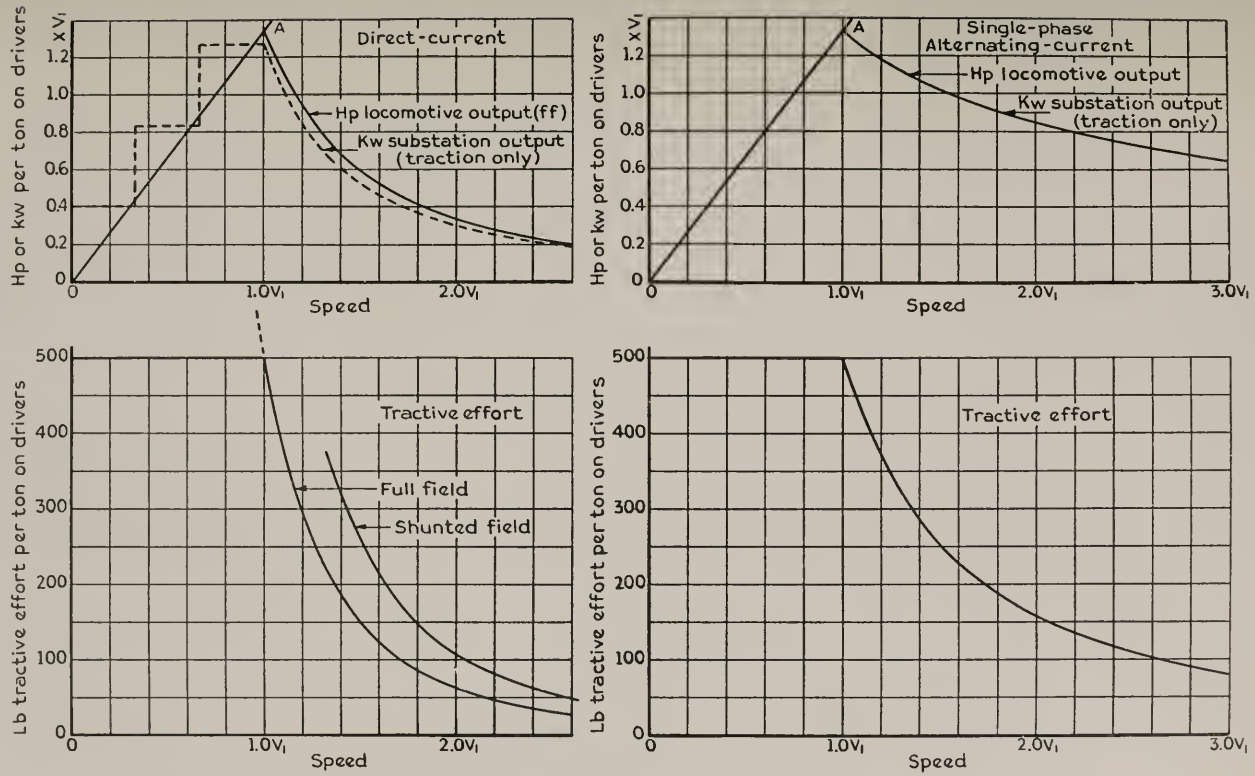


FIG. 7.—Typical Characteristic Curves, Direct-Current and Single-Phase Alternating Current.

reason it is customary to assume constant horsepower output over a wide range in speed from 60 percent speed to maximum speed. Thus in the example it would be assumed that on some tap or control point the horsepower output at $.6 \times 90$, or 54 m.p.h. is the same as at 90 m.p.h., hence the tractive effort corresponding to 54 m.p.h. on this tap is $18{,}000 \div 0.6$, or 30,000 lb.

In order not to exceed the safe overload capacity of the equipment (1.5 times normal load) when the locomotive is exerting its maximum tractive effort, the output at 54 m.p.h. must not exceed $1.333 \times V_1 \div 1.5$, or $0.888 \times V_1$, say $0.902 \times V_1$ (See Col. (e) Form D).

The tractive effort in Col. (c) and the speed in Col. (a) corresponding to $0.902 \times V_1$ is 188 lb. per ton on drivers and $1.80 \times V_1$ respectively. Hence the approximate weight on drivers should not exceed $30{,}000 \div 188$, or 160 tons and V_1 becomes $54 \div 1.80$, or 30 m.p.h. The total weight of locomotive will be 30 to 35 percent more than the weight on drivers if guiding and trailing trucks are required. The locomotive and substation outputs can now be computed by filling out Form D. Spaces are provided at the bottom of the form for computing the characteristics based on constant output or on other control points.

These examples will serve to illustrate some of the fundamental principles involved in the design and operation of electric locomotives for the purpose of comparing their performances and economic advantages with those of steam locomotives. In the final analysis the designers and locomotive builders will be able to adjust the estimates to conform to their designs and determine the horsepower rating required.

(c) Split Phase Induction Motor Locomotives

The split-phase induction motor locomotive is inherently a constant speed locomotive on account of the fact that the speeds of induction motors depend upon the frequency of the distribution system and the number of magnetic poles in the motor design.

In order to double the speed of an induction motor it is necessary to be able to reduce the number of poles to half, which is only feasible from an electrical standpoint when the number of magnetic poles is divisible by four.

The chief advantage of the split phase induction motor locomotive is due to its ability to regenerate power automatically and return it to the distribution system when operating on descending grades. All types of electric locomotives are capable of regenerating power under the same conditions if they are provided with a suitable control.

Fig. 8 shows typical characteristics of split-phase induction-motor locomotives. Their applications are limited on account of their constant-speed characteristics and for this reason the form for calculating the characteristic curves has been omitted.

(d) Motor-Generator Locomotives

Motor-generator locomotives are essentially direct current locomotives arranged to operate from a single-phase alternating-current trolley by installing a motor-generator set on the locomotive to convert alternating current into direct current.

In principle, it is the same as oil-electric locomotives with an electric motor substituted for the oil engine. However, it is not essential to provide automatic control, consequently it may have some of the characteristics of direct-current locomotives.

Fig. 8 and Form E show typical characteristic curves and a method for calculating the speed and tractive effort of motor-generator locomotives based on the horsepower capacity of the motor-generator set. Attention is called to the dotted curves on the diagram and the spaces provided on the form for calculating typical characteristic curves of the traction motors based on full voltage.

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL ELECTRIC LOCOMOTIVES
SINGLE PHASE ALTERNATING CURRENT

FORM D

sample RAILROAD

ITEM

1. Type (Wheel Arrangement)
2. Weight on Drivers (Tons) 160
3. Weight of Locomotive Total 220
4. Number of Motors

Locomotive Ratings	1-Hour	Continuous
5. Horsepower		
6. Speed		
7. Tractive Effort		

Speed		Driver Tractive Effort		Locomotive Output		Substation Output	
V	Miles per Hour	Lbs per Ton on Drivers	Total ♦	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total ★
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
0	0	500	80,000	0	0	0	0
1.00 x V_1	30.00	500	80,000	1.333 x V_1	6400	1.333 x V_1	6400
1.10 "	33.00	426	68,160	1.250 "	6000	1.250 "	6000
1.20 "	36.00	369	59,040	1.181 "	5669	1.181 "	5669
1.30 "	39.00	323	51,680	1.120 "	5376	1.120 "	5376
1.40 "	42.00	285	45,600	1.065 "	5112	1.065 "	5112
1.50 "	45.00	254	40,640	1.016 "	4877	1.016 "	4877
1.60 "	48.00	228	36,480	.973 "	4670	.973 "	4670
1.80 "	54.00	188	30,080	.902 "	4330	.902 "	4330
2.00 "	60.00	157	25,120	.837 "	4018	.837 "	4018
2.20 "	66.00	135	21,600	.792 "	3802	.792 "	3802
2.40 "	72.00	116	18,560	.742 "	3562	.742 "	3562
2.60 "	78.00	102	16,320	.707 "	3394	.707 "	3394
2.80 "	84.00	90	14,400	.671 "	3221	.671 "	3221
3.00 "	90.00	80	12,800	.640 "	3072	.640 "	3072

Supplementary Characteristic Curves

♦Driver Tractive Effort	Miles per Hour				KW Substation Output				
	V' .9	V" 1.1	1.2xV_1	1.3xV_1	Col★	V' .9	V" 1.1	1.2xV_1	1.3xV_1
59040	32.4	39.6	-	-	5669	5102	6236	-	-
51680	35.1	42.9	-	-	5376	4838	5914	-	-
45600	37.8	46.2	50.4	-	5112	4601	5623	6134	-
40640	40.5	49.5	54.0	58.5	4877	4389	5365	5852	6340
36480	43.2	52.8	57.6	62.4	4670	4203	5137	5604	6071
30080	48.6	59.4	64.8	70.2	4330	3897	4763	5196	5629
25120	54.0	66.0	72.0	78.0	4018	3616	4420	4322	5223
21600	59.4	72.6	79.2	85.8	3802	3422	4182	4562	4943
18560	64.8	79.2	86.4	93.6	3562	3206	3918	4274	4631
16320	70.2	85.8	93.6	101.4	3394	3055	3733	4073	4412
CONSTANT OUTPUT 4320 HP									
MPH	60	65	70	75	80	85	90	95	100
TE	27000	24920	23140	21600	20250	19060	18000	17050	16200

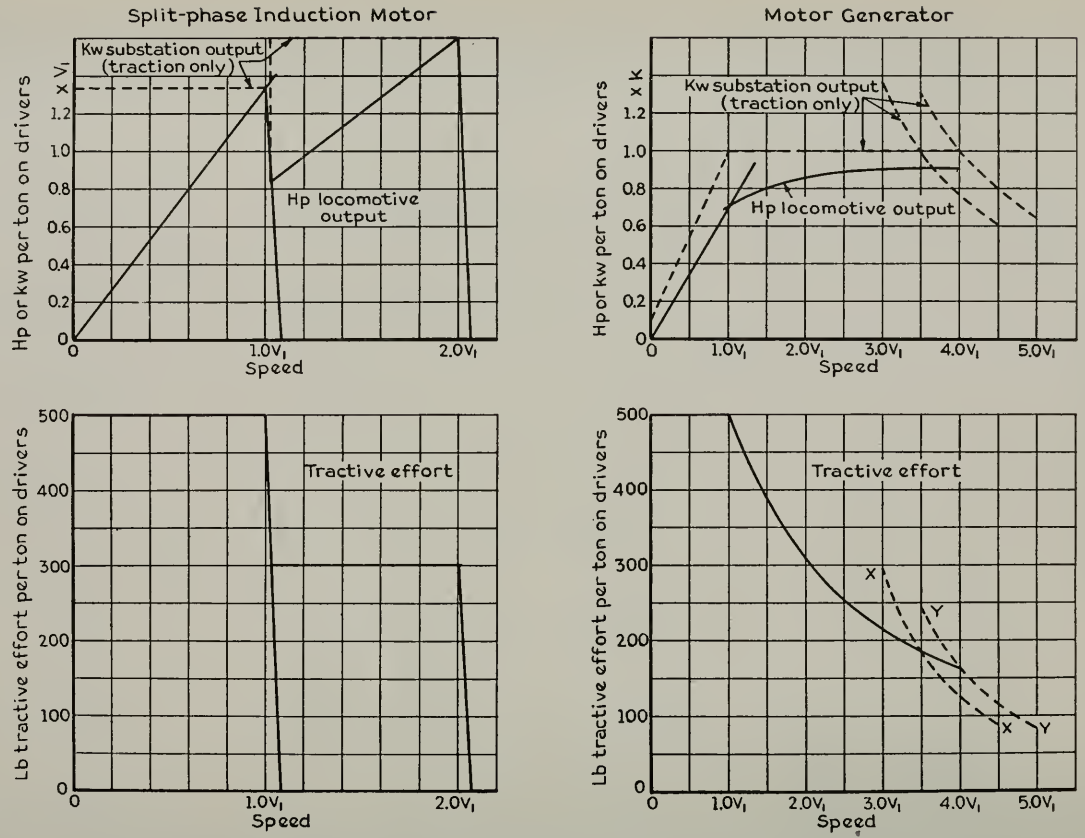


FIG. 8.—Typical Characteristic Curves, Split-Phase Induction Motor and Motor Generator.

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL ELECTRIC LOCOMOTIVES
MOTOR GENERATOR LOCOMOTIVE

FORM E

ITEM

1. Type (Wheel Arrangement)_____
2. Weight on Drivers (Tons)_____
3. Weight of Locomotive (Tons)_____

4. HP Rating of Mot-Gen Set_____
5. Max HP Rating (Pull Out) M-G Set_____

6. Rated Speed_____

7. Rated Tractive Effort_____

8. Rated HP M-G Set Per Ton on Drivers = K_____

9. V = .522 x Item (8)_____

	Speed		Driver Tractive Effort		Locomotive Output		Substation Output	
	V	MPH	Lbs per Ton on Drivers	Total	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
	0	0	500		0	0	.100 x K	
	1.00 x V_1		500		.696 x K		1.000 "	
	1.25 "		437		.760 "		1.000 "	
	1.50 "		386		.805 "		1.000 "	
	1.75 "		344		.837 "		1.000 "	
	2.00 "		308		.858 "		1.000 "	
	2.25 "		279		.874 "		1.000 "	
	2.50 "		254		.884 "		1.000 "	
	2.75 "		233		.892 "		1.000 "	
	3.00 "		215		.897 "		1.000 "	
x	3.50 "		185		.902 "		1.000 "	
y	4.00 "		163		.907 "		1.000 "	

Traction Motor Characteristics Full Gen. Voltage

	3.00 x V_1		294		1.228 x K		1.362 x K	
	3.25 "		231		1.046 "		1.160 "	
x	3.50 "		185		.902 "		1.000 "	
	4.00 "		124		.690 "		.765 "	
	4.50 "		87		.545 "		.605 "	

	3.50 x V_1		244		1.185 x K		1.307 x K	
	3.75 "		198		1.032 "		1.138 "	
y	4.00 "		163		.907 "		1.000 "	
	4.50 "		114		.716 "		.790 "	
	5.00 "		83		.580 "		.640 "	

xy Note effect of constant generator voltage

Electric Braking

There are two forms of electric braking which convert the stored energy in the train into electric energy and thus reduce the heating and wear of brake shoes and wheels. In one form which is known as dynamic braking the electric energy is wasted in heating resistances which are carried on the locomotive for this purpose. In the other form which is called regenerative braking, the electric energy is returned to the distribution system where it does useful work supplying power to other trains on the line or reducing the load on the power station.

When calculating the amount of power which can be converted into electric power it is necessary to consider the tractive capacity of the locomotive and the characteristics of the electrical equipment as well as the grades and the resistance of the train. Part of the stored energy of the train is lost in overcoming train resistance, the balance represents the amount available for conversion into electric energy.

Braking Effort

The braking effort of a locomotive is the force exerted at the driving axles to oppose its motion or the opposite of tractive effort. The maximum braking power of a locomotive is therefore limited by the same conditions which limit its maximum tractive power, except in practice it is customary to limit the maximum braking effort to 20 per cent of the weight on drivers instead of 25 per cent which is the amount generally assumed as the maximum tractive effort available for propelling the locomotive. Thus the tractive and braking capacities of a locomotive can be represented by the lines O-A and O-A′ respectively in Fig. 9.

The actual amount of electric power which can be generated is limited by the capacity of the equipment, its efficiency and characteristics. A typical tractive effort and regenerative braking diagram is shown in Fig. 9.

In the left-hand portion of the diagram the horsepower outputs of the locomotive when motoring are shown above the horizontal axis and the horsepower inputs to the drivers and the electrical outputs in kilowatts when braking, are shown below the horizontal axis. In the right-hand portion of the diagram the tractive efforts at various speeds are shown above the horizontal axis and the braking efforts below. The tractive effort characteristics are based on an allowance of about 10 percent for average voltage drop in the trolley, whereas no allowance has been made for over-voltage or voltage drop during regeneration because it is assumed that a kilowatt generated at the locomotive is equivalent to a kilowatt generated at the substation. Actually, there will be times during regeneration when the voltage at the locomotive will be higher than at the substation but in preliminary estimates this condition can be neglected.

Form F shows a work sheet for calculating the braking efforts obtainable at various speeds based on full speed and two-third speed connections. Spaces are left at the bottom of the form for calculating the braking efforts corresponding to one-half or one-third speed combination whichever combination is applicable to the particular locomotive in question. (One-half applies when the number of motors is a multiple of four and one-third when it is a multiple of six).

When applying these data to actual examples it is sometimes found that the braking efforts required to hold the train at the desired speed are less than given on the diagram or on the form. In these cases it is necessary to reduce the power regenerated in proportion to the braking efforts. When the braking efforts required to hold the train at the desired speed are greater than obtained on the form, it is necessary to assume that the excess braking effort will be supplied by the brakes on the train.

FORM FOR CALCULATING THE BRAKING EFFORT AND KW OUTPUT REGENERATED TYPICAL DIRECT CURRENT LOCOMOTIVES

FORM F

_____RAILROAD

Item

1. Type (Wheel Arrangement)_____
2. Weight on Drivers (Tons)_____
3. Weight of Locomotive_____
4. Number of Motors_____

5. Horsepower Continuous Rating_____
6. Speed at Continuous Rating_____
7. Tractive Effort Continuous Rating_____

8. T.E. Continuous Rating per Ton on Drivers_____
9. Speed (Cont. Rating) Corrected for Ave Line Voltage_____

10. Maximum Safe Speed MPH_____

Full Speed		Driver Braking Effort		Input Locomotive		Output Locomotive	
V	MPH	Lbs per Ton on Drivers	Total	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total
1.00 x V_1							
		Fill out above spaces from Form C					
1.20 x V_1		0	0	0	0	0	0
1.30 "		400		1.387 x V_1		.900 x V_1	
1.40 "		400		1.494 "		.970 "	
1.50 "		373		1.494 "		.970 "	
1.60 "		350		1.494 "		.970 "	
1.80 "		311		1.494 "		.970 "	
2.00 "		227		1.210 "		.790 "	
2.20 "		171		1.004 "		.650 "	
2.40 "		131		.838 "		.550 "	
2.60 "		103		.714 "		.460 "	
2.80 "		83		.620 "		.400 "	
3.00 "		67		.536 "		.350 "	

2/3 Speed

.800 x V_1		0		0		0	
.867 "		400		.925 x V_1		.600 x V_1	
.933 "		400		.996 "		.647 "	
1.000 "		373		.996 "		.647 "	
1.067 "		350		.996 "		.647 "	
1.200 "		311		.996 "		.647 "	
1.333 "		227		.807 "		.527 "	
1.467 "		171		.670 "		.433 "	
1.600 "		131		.559 "		.367 "	
1.733 "		103		.476 "		.307 "	
1.867 "		83		.413 "		.267 "	
2.000 "		67		.357 "		.233 "	

Speed

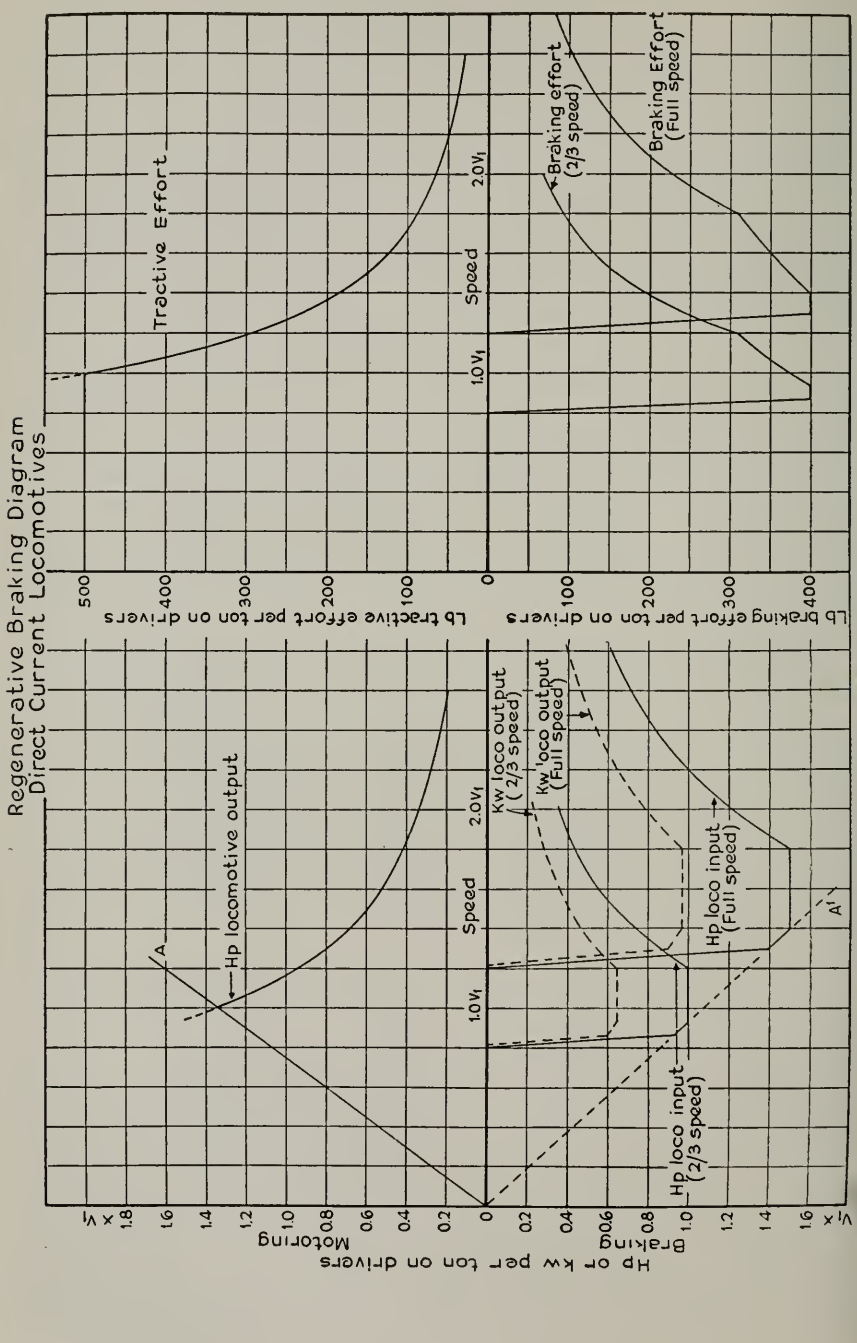


FIG. 9.—Regenerative Braking Diagram Direct Current Locomotives.

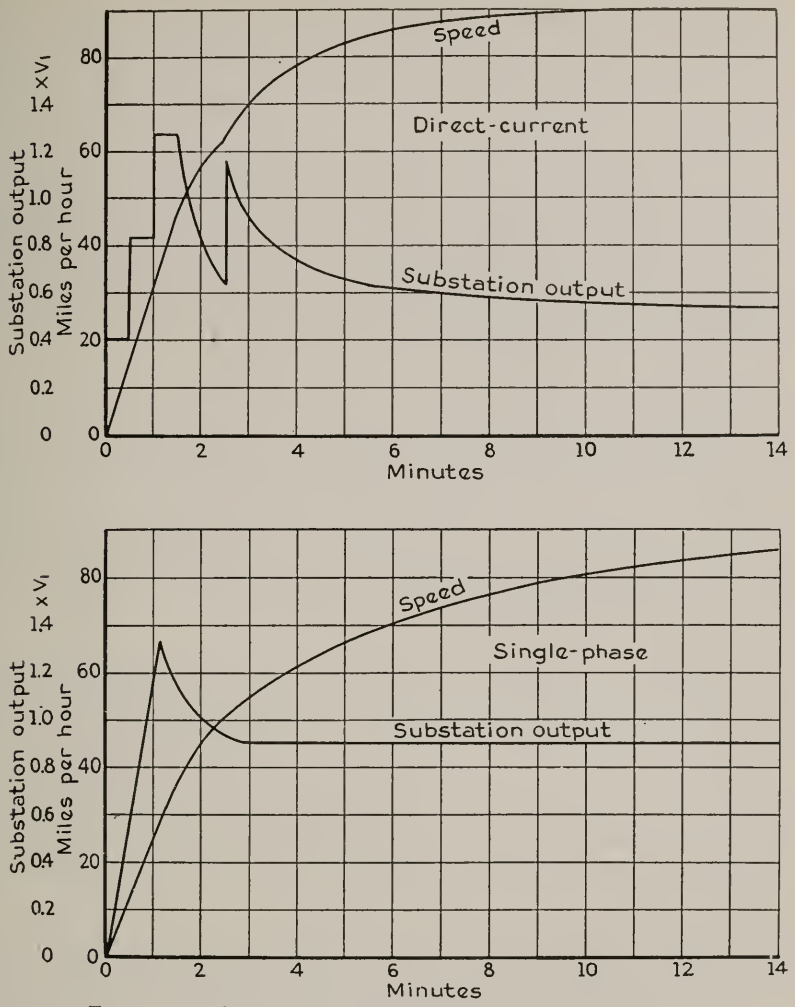


Fig. 10.—Typical Speed-Time and Energy Consumption Curves Electric Locomotives.

For examples, see page 463, Proceedings for 1938, Vol. 39.

For preliminary calculations it can be assumed that effective braking for all types of electric locomotives can be obtained within the range indicated on Form F. In the case of motor generator locomotives adjustments for losses in the motor generator set have to be made when estimating the amount of power returned to the line.

Performance and Energy Consumption of Electric Locomotives

Fig. 10 shows typical speed-time and substation-output curves for direct-current and single-phase alternating-current locomotives. The data for plotting the substation output curves can be obtained by referring to Forms C or D and plotting substation outputs at various times corresponding to the speeds at those times.

Thus, in the direct-current case a speed of 72.5 m.p.h. is reached in about 3.2 min. For this locomotive a speed of 72.5 m.p.h. corresponds to about 1.56 V_1, which in turn corresponds to a substation output of $0.866 \times V_1$ per ton on drivers in the shunted field position. The point on the substation output curve corresponding to 3.2 min. is therefore $0.866 \times V_1$.

OIL-ELECTRIC LOCOMOTIVES AND RAIL CARS

Oil-electric locomotives are examples of a type of motive power which uses electrical means for transmitting power from a power unit to the drivers. Other examples which can be included in this class are gas-electric rail cars and turbo-electric locomotives. In all cases the basic principles are the same as for steam locomotives, except that in some instances different limits are assumed, as explained later.

Tractive Capacity

The maximum tractive capacity is limited by the adhesion between the drivers and the rails, which in the case of oil-electric locomotives is generally based on 30 percent of the weight on drivers instead of 25 percent used for steam locomotives, because the tractive effort which can be developed by overloading the traction motors is not a fixed maximum as it is in the case of steam locomotives. However in some cases it is necessary to limit the maximum tractive efforts arbitrarily to avoid exceeding the overload capacity of the electrical equipment. It is represented by the line O-A, Fig. 11.

Power Capacity

The amount of power available is limited the same as for steam locomotives by the capacity of the power unit (usually the manufacturer's rating) which is represented by the horizontal line E-C Fig. 11. The maximum capacity is represented by the line E′-C′.

In some cases the power unit supplies power for operating the auxiliaries, such as air compressor, blowers, battery charging, etc. which amounts to two to seven per cent of the rated capacity. The balance after deducting the power required for auxiliaries is the power available for traction and is represented by the horizontal line E″-C″, Fig. 11.

Locomotive Output

The locomotive output in the case of electric drive is equal to the engine output less the power required for auxiliaries, less the electrical and mechanical losses in the transmission. In practice the characteristics and efficiencies of motors and generators can be accurately determined from stand tests before the equipment is assembled on the locomotive. The control can then be designed and adjusted to limit the output of the power unit to any desired amount by compensating for the losses in the transmission.

In general the combined efficiency of motors and generators corresponding to normal ratings will amount to 81 to 83 percent depending upon their capacity. If no allowances are necessary for auxiliaries, the nominal horsepower output of locomotive can be taken at 81 to 83 percent of engine capacity. If an allowance of 2 to 4 percent is made for auxiliaries, the nominal horsepower output will be around 80 percent.

If it is necessary to allow seven percent for auxiliaries, it is usually assumed that the equipment is small and the efficiency is *less* than for larger equipment. In this case the nominal horsepower output may be as low as 73 percent of the engine output, but 75 percent is generally assumed.

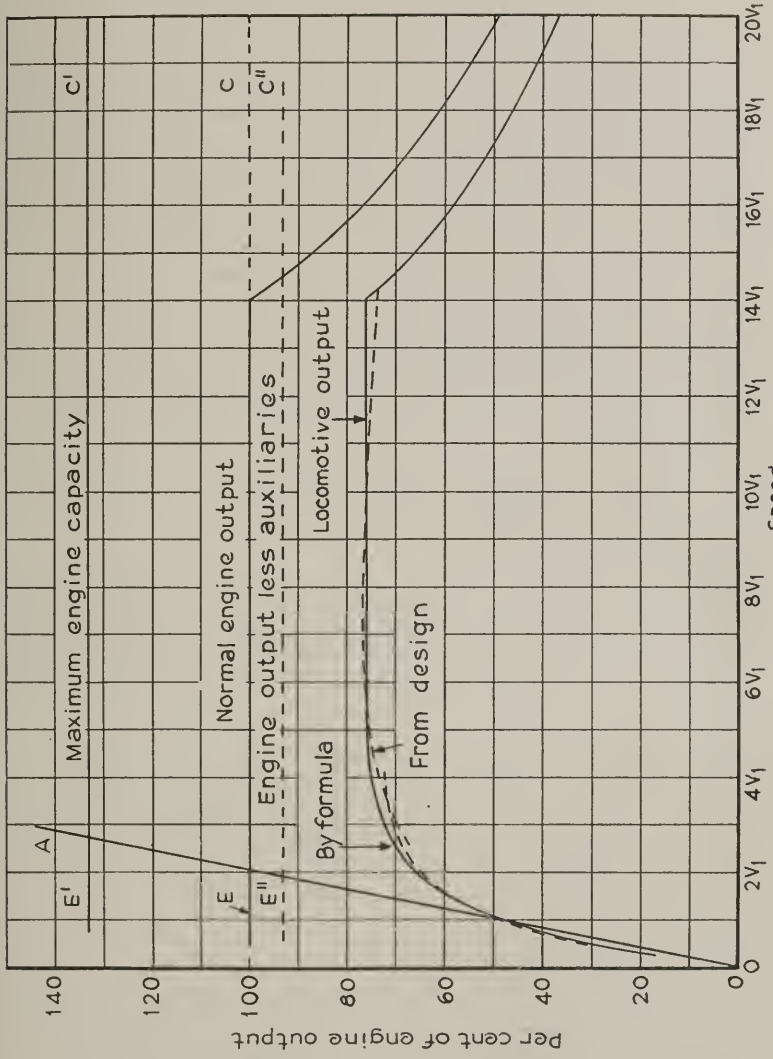


FIG. 11.—Typical Horsepower Curves Oil Electric Locomotives.

The dotted curve in Fig. 11 shows the horsepower output at the driving axles computed from design data. The solid curve is obtained by using Form G, which is based on an empirical formula similar to the one derived for steam locomotives.*

Speed Tractive Effort Curves—Oil Electric Locomotives

Form G shows a typical work sheet similar to the ones for steam and electric locomotives for calculating the speed, tractive effort and horsepower outputs of oil-electric, or turbo-electric locomotives and gas-electric rail cars based upon the horsepower capacity of the power unit and the weight on drivers. The speeds and driver tractive efforts corresponding to normal gearing are calculated first and entered in Cols. (b) and (d) and the horsepower outputs in Col. (k). For normal gearing, $V_1 = 0.395 \times K$ and corresponds to a tractive effort of 600 lb. per ton on drivers or 30 percent of the weight on drivers.

This gearing which usually corresponds to maximum reduction (minimum motor pinion) limits the speed range over which the full capacity of the power unit can be used to about $10 \times V_1$ without shunted field and to about $14 \times V_1$ with shunted field control, provided the generator is wound for the same voltage as the motors. At higher speeds the tractive efforts fall off rapidly with increases in speed due to the characteristics of the electrical equipment which automatically reduces the load on the power unit.

The reduced horsepowers (U), (X), (Y) and (Z), which correspond 10, 20, 30 and 40 percent increases in V', are given in order to be able to adjust the tractive efforts at these high speeds and reduced outputs. The speed represented by V' may correspond to any value of V between $8 \times V_1$ and $14 \times V_1$, depending upon design data—motor and generator voltages, type of control, etc.

If it is desired to use the full capacity of the power unit over a higher speed range than indicated for normal gearing, it is necessary to change the motor gearing. For example, if it is desired to obtain full engine capacity up to $20 \times V_1$ instead of, say, $10 \times V_1$ the speeds in Col. (b) would be doubled and entered in Col. (e) and the tractive efforts in Col. (d) would be halved and entered in Col. (f). The speeds and tractive efforts corresponding to any other gear ratio would be obtained in like manner and entered in Cols. (g) and (h).

In the case of double speed gearing, for example, the tractive effort for the same overload on the electrical equipment would be limited to 300 lb. per ton on drivers, otherwise the losses might be excessive and the overloads injurious to the equipment. For these reasons it is necessary to depend upon designing engineers for the final selection of equipment and gearing to meet operating conditions.

Example 8. Calculate the typical speed tractive effort curve of the following switching locomotive.

B-B-234 ÷ 234-900-hp. oil-electric locomotive

Continuous rating 33,600 lb. at 8.1 m.p.h.

Solution.—Rated tractive effort per ton on drivers equals $33{,}600 \div 117$ or 287 lb. Refer to Form G and find in Col. (c) 300 and 263 lb. corresponding to $3 \times V_1$ and $3.5 \times V_1$ respectively. By interpolation, 287 lb. corresponds to $3.31 \times V_1 = 8.1$ m.p.h. or $V_1 = 2.447$ m.p.h. and K, nominal horsepower per ton on drivers, $= 2.447 \div 0.395$, or 6.197 and the nominal horsepower output of the locomotive equals 117×6.197, or 725.

* The formula is

Horsepower output per ton on drivers $= K\,(1 - e^{-u})$

where K = nominal horsepower output per ton on drivers

e = base of Naperian logarithms

$$u = \frac{V}{V_1}$$

V and V_1 = speeds in miles per hour

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF OIL-ELECTRIC LOCOMOTIVES

FORM G

_____RAILROAD

Item

1. Type (Wheel Arrangement)_____
2. Weight on Drivers (Tons)_____
3. Weight of Locomotive_____

4. Rated Horsepower of Power Unit_____
5. Horsepower Required for Auxiliaries_____
6. *Nominal Horsepower Output of Locomotive_____

7. Horsepower per ton on Drivers Item (6)/Item (2) = K_____
8. V_1 = .395 x Item (7)_____

Normal Gearing				Special Gearing				Horsepower Output	
Speed		Driver		A		B			
		Tractive Effort							
V	MPH	Lbs.Per Ton on Drivers	Total	MPH	Driver T.E. Total	MPH	Driver T.E. Total	Per Ton on Drivers	Total
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)
0	0	600		0		0		0	0
1.00xV1		600						.632xK	
1.25 "		542						.713 "	
1.50 "		492						.777 "	
1.75 "		448						.826 "	
2.00 "		411						.865 "	
2.50 "		348						.918 "	
3.00 "		300						.950 "	
3.50 "		263						.970 "	
4.00 "		233						.982 "	
4.50 "		209						.989 "	
5.00 "		189						.993 "	
6.00 "		158						.998 "	
7.00 "		135						.999 "	
8.00 "		119						1.000 "	
10.00 "		95						1.000 "	
12.00 "		79						1.000 "	
14.00 "		67						1.000 "	
1.10xV'								(U).826 "	
1.20 "								(X).694 "	
1.30 "								(Y).592 "	
1.40 "								(Z).510 "	

*Nominal horsepower output of locomotive depends upon engine capacity and allowances for auxiliaries.

Assume 80 per cent (78-82) of Item (4) for road locomotives
75 per cent (73-77) of Item (4) for switch locomotives and rail cars including auxiliaries

(U) (X) (Y) (Z) are the horsepower outputs corresponding to 10, 20, 30 and 40 per cent over speed (after generator reaches full voltage)

Spaces A and B are provided in case it is necessary to change motor gearing to meet high speed conditions.

The items 1 to 8, Form G, can now be filled in as follows and the speed tractive effort curves calculated.

1.	Type (wheel arrangement)	B-B
2.	Weight on drivers—234,000 lb.	117 tons
3.	Weight of Locomotive—234,000 lb.	117 "
4.	Rated horsepower of power unit	900
5.	Horsepower required for auxiliaries	
6.	Nominal horsepower output of locomotive (see above)	725
7.	Horsepower per ton on drivers	6.197
8.	$V_1 = 0.395 \times 6.197$	2.447

Locomotive Classification

The design and construction of oil-electric locomotives and others of this class have followed along the lines of electric locomotives and motor cars, therefore it is customary to classify them by their wheel arrangement in accordance with the electric system described earlier.

Weight and Capacity

At the present time there are not sufficient statistical data available to attempt an analysis of the relation between engine horsepower capacity and weight of locomotive along the lines discussed in the sections on steam and electric locomotives. For preliminary estimates regarding weights it can be roughly assumed that for the same horsepower capacity, oil-electric locomotives will weigh more than the engine and nearly as much as the engine and tender of steam locomotives as determined by Table 2. At the same time, oil electric locomotives will generally have two or more times as many driving axles as steam locomotives of the same capacity and, hence, can have nearly twice as much weight on drivers, therefore the maximum tractive effort in some cases can easily be twice as much in starting as that for comparable steam locomotives.

This report completes the study of various types of motive power in relation to the subject of II Power and explains the development and application of various forms for calculating typical characteristic curves of the principal types of locomotives. It is assumed that the forms with brief instructions in regard to their use will be sufficient for manual purposes if reference is made to the foregoing report and those in the Proceedings, Vol. 38 and 39, for a full discussion of the basic principles.

It is recommended that the report be received as information.

Appendix B

(2) METHODS FOR OBTAINING A MORE INTENSIVE USE OF EXISTING RAILWAY FACILITIES

L. E. Dale, Chairman, Subcommittee; E. Y. Allen, B. T. Anderson, E. B. Crane, G. W. Hand, E. A. Humphreys, W. B. Irwin, J. F. Pringle, C. P. Richmond, B. J. Schwendt, L. K. Sillcox, H. W. Williams.

Previous Work of Committee

The subject of this report was first assigned to Committee 22 in June, 1925 as, "Methods of operation by which the intensive use of facilities may be secured." Under this phrasing of the problem two reports were submitted:

(1) March, 1926—Brief progress statement.

(2) March, 1927—Brief statement of progress on the investigation of (1) No. 19 train order in place of No. 31 order, (2) CPR and CNR methods of handling peak load grain traffic.

The assignment was revised, in June 1927 to read, "Develop and report on methods for obtaining a more intensive use of existing railway facilities, with particular reference to increasing carrying capacity: (a) Without material additional capital expenditure; (b) With due regard to reasonable increase in capital expenditures consistent with traffic requirements."

Under this statement of the subject seven reports were submitted as follows:

(1) March, 1928—Study of a heavy traffic single-track railway to show what traffic can be handled. Description of line, signals, power; account of improvements to line and power. Operating statistics and charts showing increase in traffic handled, conclusions.

(2) March, 1929—General statement showing improved performance of the railroads in the United States as a whole. Exhibit A (28 pages) on method of determining most economical train length, considering all factors. Exhibit B (14 pages) study of 345-mile division showing improvements in operating performance resulting from increasing double track from 43 miles to 101 miles. Conclusion directs attention to other factors that affected the results.

(3) March, 1930—Report on results obtained by first installation of centralized traffic control on 40 miles of line.

(4) March, 1931—General analysis of problem of maximum use of existing facilities —consideration of spacing system, dispatching speed, tonnage rating, condition of track and equipment, service facilities, yard design, etc. Study of increase in capacity made possible by providing additional facilities—embraces use of train (time-space) charts as well as train-hour charts. Summary covers effect of double-tracking, supervision, heavier power, signals, C.T.C., Exhibit A discusses similarity between typical train-hour diagram and probability curve. (Total report 50 pages.)

(5) March, 1932—Offers general conclusions for Manual that were adopted. Also a study of the conversion of a double-track line to single track.

(6) March, 1933—Forecast of improvements in train operation on a single-track line with short sections of double-track, equipped with spring switches and C.T.C. automatic block; also factors to be considered in comparing the present track layout and method of train operation with the proposed track layout and C.T.C. manual block method of train operation.

(7) March, 1935—Report on methods adopted and results obtained by co-ordination of facilities of two parallel railways at a wayside station.

In May, 1935—The assignment was again revised to read "Methods for obtaining a more intensive use of existing railway facilities." Under this statement of the subject two reports have been submitted.

(1) March, 1937—Co-ordination of facilities—an exposition of the basic principles involved—with particular reference to trackage rights' agreements and joint ownership agreements.

(2) March, 1938—Pooling of traffic—brief description of nine different arrangements in effect involving facilities used jointly by two or more roads.

Current Report

Discussion of this assignment by your committee emphasized the current importance of co-ordination as a method of obtaining more intensive use of existing facilities and the desirability of a general examination of facilities jointly used and the conditions under which such use is accomplished.

The joint use of the facilities of one railroad by another is a common practice that has developed progressively since the early days of railroading. The use of the property of one railroad by another has almost always been brought about through the so-called "Joint Facility Agreements" which had their inception in the desire of one or more parties to make use of existing facilities of another, thus avoiding the investment in and maintenance of duplicate facilities to the mutual advantage of all concerned. It was recognized that there was some element of profit to the owner through the receipt of a fair interest rental charge, together with percentages charged on labor and material expended in the maintenance and operation of the jointly used property. The almost universal use of joint facility arrangements during this long period of time has resulted in the establishment of principles generally understood and almost uniformly applied. In certain regions, rules and percentages covering their uniform application have been made effective by the railroads.

Of more recent origin is a basis for the common use of facilities termed "Co-ordination". This results from the desire to realize the economies made possible by the abandonment of duplicate facilities and services, the resulting economies being divided on an equitable basis—generally shared equally by the participating carriers. Where a project is relatively simple, such as the abandonment of a parallel branch line, co-ordination can be accomplished without complications resulting from a consideration of property rights and traffic advantages. On account of difficulty encountered in nearly all projects, in accurately appraising the effect of co-ordination arrangements on individual properties, no concensus has as yet developed to make possible any general acceptance of principles to cover a co-ordination basis of common use.

The extent of joint use of facilities by Class I Railroads in the United States as of December 31, 1923, was determined by the Bureau of Railway Economics to be as follows, the amounts shown being net totals, which exclude duplications:

Tracks—Miles, first main track	12,165
Miles, other tracks	12,234
Terminals—Number of engine terminals	268
Number of L.C.L. freight houses (*)	1,336
Number of passenger stations (*)	1,902
Number of yards	618
Number of large bridges	472

* Includes 151 combination freight and passenger stations.

These facilities were used jointly on the basis of agreements that provided for a division of common maintenance and transportation costs in proportion to use, and a division of annual capital costs and taxes and, when required to preserve equities inherent in ownership, restrictions or limits as to extent of use by the tenant line. Agreements such as these were mutually advantageous to the lines participating.

The above statement reports that 5½ percent of all "First Track" and 8 percent of "All Other Tracks" were jointly used in 1923. When it is considered that there is also included the Grand Central Terminal and the Pennsylvania station at New York; the LaSalle Street, Union, Dearborn, Illinois Central and Grand Central stations at Chicago; South Station at Boston; the Union Station at Washington; and the Kansas City Union Station; the facilities of the St. Louis Terminal Association; and the many joint operations effective in large centers of population throughout the United States, it is evident that the investment in facilities jointly used is very large and constitutes an appreciable part of the total railroad investment in "Road." It is apparent that the economic advantage of the elimination of costs for interest, taxes, and operation and maintenance of duplicate facilities, the construction and operation of which were avoided by joint use, contributes materially to reducing the cost of railroad transportation.

Railroad freight traffic reached a peak during the years 1925–1929, when car loadings averaged 1,000,000 cars per week, the total loading for these 5 years having been 260,376,589, or an annual average of 52,075,318. During 1932, loadings were 28,179,952, and during 1933 they were 29,220,052. This drop of about 45 percent from the 1925–1929 average resulted in a large excess capacity of existing facilities above that needed to handle the greatly diminished volume of traffic.

Joint use under such conditions became a problem of co-ordination of competitive facilities and services, for the purpose of making possible the retirement of excess facilities and a reduction in costs as a result of consolidated operations. This phase of the problem of joint use was given consideration by the railroads by means of regional committees on elimination of preventable waste. The consolidation of yards, terminals, engine houses, mechanical facilities, freight and passenger stations, city ticket offices, car ferries, inspection bureaus, competitive train service, package standards, industrial switching, mine runs and joint trackage was studied in the interest of the railroads, individually and collectively. On June 16, 1933, The Emergency Railroad Transportation Act became effective, which created the office of federal co-ordinator, provided for the organization of regional co-ordinating committees and for action that would avoid unnecessary duplication of services and facilities of whatever nature, and permit the joint use of terminals and trackage incident thereto or requisite to such joint use.

It also provided that, "The number of employees in the service of a carrier shall not be reduced by reason of any action pursuant to the authority of this title below the number as shown by the payrolls of employees in service during the month of May 1933, after deducting the number who have been removed from the payrolls after the effective date of this act by reason of death, normal retirements, or resignation, but not more in any one year than 5 per centum of said number in service during May 1933; nor shall any employee in such service be deprived of employment such as he had during said month of May or be in a worse position with respect to his compensation for such employment, by reason of any action taken pursuant to the authority conferred by this title."

The above is Section 7(b) of the act—and has been quoted verbatim.

A total of 5,124 projects was reported by the co-ordinating committees as having been docketed for study and report by special committees, each composed of representa-

tives of the individual railroads. At the termination of the federal co-ordinator's office on June 15, 1936, the status of these projects was as follows—

		Number
(1)	Accomplished	105
(2)	Considered and postponed on account of Section 7(b)—Emergency Railroad Transportation Act	703
(3)	Considered and postponed because of heavy capital expenditures required, and mortgage and contract obligations	63
(4)	Considered and dropped because of lack of merit, phy ically impossible, etc.	4,226
(5)	Pending	27
	Total Projects	5,124
(6)	Employees affected by 7(b) Projects—Item (2)	12,858

These studies and reports were made in accordance with the following instructions:

1. Co-ordinated operations to be interpreted to mean a complete submergence of all corporate indentity within the limits considered.

2. To disregard all questions of corporate management.

3. To extend the area to be considered to embrace joint trackage beyond terminal limits when such joint trackage would be a factor in terminal handling and productive of saving.

4. To disregard the necessity of unanimous agreement either within the various committees or of lines not holding representation on the committee as long as the plans suggested are considered practicable and workable by a majority.

5. To give thought to the effect of store-door delivery and pick-up of L.C.L. freight when such an arrangement is thought desirable and report on the economies which would be produced when the possibilities are greater than without it. When the two approach each other with reasonable closeness to report on the smaller as an alternative scheme, using the plan showing the larger saving in the summary.

6. To give special attention to the consolidation of yards when considerable transfer operations can be avoided thereby.

7. To include operations contingent upon capital expenditures when the saving to be anticipated therefrom clearly justifies such expenditure.

Co-ordination that contemplates a reduction in facilities involves the displacement of employees. Section 7(b) of the Emergency Transportation Act covered the detail of protecting an employee against being deprived of employment as a result of co-ordination of facilities. No basis was provided, however, covering the condition resulting when the employee's work was eliminated and there would be no duties for him to perform.

The so-called Washington agreement was signed on May 21, 1936 by representatives of practically all Class I Railroads and their organized employees. This agreement fixes the status of employees affected by co-ordination projects, provides that no employee affected by a particular co-ordination and who is continued in service shall be placed in a worse position, with respect to compensation and rules governing working conditions, for a period not exceeding five years than he occupied at the time, so long as he is unable in the normal exercise of senority rights to obtain a position producing compensation equal to or exceeding that of position held, and for the payment of specified displacement and separation allowances under defined conditions.

In June 1936, the board of directors of the Association of American Railroads arranged that projects on which action had been postponed by the co-ordinating committees on account of the provisions of Section 7(b) of the Emergency Railroad Trans-

portation Act of 1933 and such other projects as may be presented, be studied by appropriate committees to the end that economies indicated as possible may be accomplished. The necessary studies have been proceeding since that time and as of July 15, 1938, the status of these projects was as follows—

	Number
Accomplished	26
Dropped	617
Total Reported	643
Pending	89

The following comments briefly review experience with terminal co-ordination studies covering facilities located in numerous large railroad centers:

At the outset it will be recognized that in almost any large terminal there are presently existing depot companies operating joint passenger stations; transfer companies operating joint freight yards for interchange of carload traffic, joint freight stations, zone-switching districts; and numberless joint-facility arrangements of lesser magnitude, many of which were established 50 or 75 years ago, the objective then, as now, being economy and improved service.

The formation of a completely consolidated or "universal terminal", in which all property and facilities are owned in common and competitive features eliminated, involves a further co-ordination of all facilities and service within the selected area, including not only the unification of all separately owned and operated facilities, but the absorption of presently existing terminal companies and joint facilities as well, the whole to be operated by a general organization established for that specific purpose.

The solution of these problems requires the assignment of officers skilled in negotiation, having intimate knowledge of the terminal district, and freed from their regular duties for the time-consuming conferences entailed in consummating the project. In the matter of procedure for the present consideration of this subject it is assumed that a competent and comprehensive analysis of all operations within the terminal district has demonstrated the possibility of a sufficient operating saving to warrant the complete co-ordination of facilities and service. It is evident that before the universal terminal can be established it will be necessary to solve problems inherent in property rights, loss of traffic advantages, and in rights of employees.

In various terminal studies it has been disclosed that in order to effect a maximum saving through co-ordination of Terminal "A" there is required a pooling of train service between Terminal "A" and next terminal "B" served by the same carriers as Terminal "A", the pooled train service in turn indicating that co-ordination of Terminal "B" is required to realize the ultimate maximum in economy. This progression might be repeated indefinitely, but for the present purpose it will be considered that competitive conditions shall continue outside the terminal area, and competition shall be eliminated as to the operation of the universal terminal.

Property Rights

Various phases of property rights are involved in terminal co-ordination, including—

(A) *Adequate Property for the Consolidated Operation*—This involves pooling of present carrier-owned property, to be used in common, and the acquisition of additional property for expansion of existing facilities, because of the concentration of service requirements in some portions of the terminal area under the co-ordination. There is involved here the liquidation of existing terminal companies, or the amalgamation of

their properties and obligations with the universal terminal, as well as the financing of the acquisition of additional property and of the capital expenditures for additional facilities entailed in consummating the project. The universal terminal is not of a temporary nature, capable of being readily discontinued and re-established with fluctuations in the general level of business. Terminal property and facilities adequate for the combined business in a peak year must be provided.

Most of the existing terminal yards were constructed in accordance with operating practices of 25 to 50 years ago. They were enlarged piecemeal as the volume of traffic increased, and have been barely adequate for the business of individual carriers during periods of heavy traffic. Many terminal properties have become so hemmed in by contiguous industrial development, arterial thoroughfares, grade separations and railroad crossings at grade that they can be expanded only at very large cost, if at all; consequently consideration must be given to the location of the required facilities for the universal terminal in outlying districts where property is cheaper.

(B) *Property Rights Involving Competitive Features*—Such property rights possess intangible worth, difficult to evaluate in a practical manner. The ownership of property in a preferential location, the possession of property rights other than fee, such as a lease of property, a grant of the use of trackage, or an exclusive-user franchise, constitute competitive features for which the possessor must be adequately compensated by the universal terminal company.

(C) *Disparity in Values of Property Provided by the Several Carriers for Consummation of the Universal Terminal*—Under presently existing terminal arrangements one carrier may have a small investment in freight station and mechanical facilities, for example, without participating in ownership of any terminal company; a second carrier may enter a terminal under trackage rights and participate in ownership of a terminal company—freight, passenger or both; a third carrier may have invested millions of dollars in extensive terminal facilities for its own use, in addition to participating in the ownership of a terminal company. It is recognized that a carrier having an investment in facilities adequate for its own needs—even if admittedly inferior to those provided by the universal terminal company for the same class of service—cannot afford to abandon its facilities and assume terminal obligations at a greater cost for use of the superior facilities in order to consummate terminal co-ordination. These disparities must be harmonized and an equitable solution reached.

(D) *Miscellaneous Factors Involving Property Rights*—

1. Suitable provision will be required for present individually-owned facilities made available for joint use.

2. Abandonment of individually-owned terminal yards, stations and mechanical facilities, because of co-ordination, will result in the reclassification as non-operating property of considerable areas, which will become subject to local taxation, with a consequent increase in taxes, properly an obligation of the universal terminal company.

3. An adjustment of mortgages and equipment trusts will be required, transferring from individual carriers to the universal terminal company the obligations for real estate, structures and equipment furnished for the consolidated operation.

Loss of Traffic Advantages

Traffic advantages, closely allied to property rights, are of two general classes and should be considered from the premise that the conception of the universal terminal is designed to provide service equal at least to that provided under individual operation

within the terminal area and at a lower cost. Therefore, the effect upon traffic conditions requires a determination of loss of traffic through the following factors:

(A) Surrender of valuable rights inherent in individual ownership of terminal property due to its favorable location with respect to industrial areas or jobbing centers.

(B) Loss of identity of individual carriers within the terminal area due to change in service relations as between the carriers and the shipping public.

Rights of Employees

The labor provisions of Section 7(b) of The Emergency Transportation Act acted as a check to co-ordination. The provisions of the so-called Washington Agreement defer the full realization of savings for a period from 3 to 5 years, and the practical difficulty of forecasting conditions so far in the future is a deterent to co-ordination. Adjustments must be made in seniority rosters as required by the transfer of employees from the rosters of individual carriers to the rosters of the universal terminal company, and in labor schedules to harmonize the claims of employees to the sole right to perform all service in the properties of individual carriers, which would be absorbed in the service to be performed by the employees of the universal terminal company.

No solution of these problems can be reached without a willingness on the part of all carriers to co-ordinate.

The foregoing comments are not presented as arguments tending to deter co-ordination, but merely for the purpose of outlining some of the important factors that prevent early consummation of terminal co-ordination projects.

It is recommended that this report be received as information.

Appendix C

(3) METHODS OR FORMULAS FOR THE SOLUTION OF SPECIAL PROBLEMS RELATING TO MORE ECONOMICAL AND EFFICIENT RAILWAY OPERATION

C. H. R. Howe, Chairman, Subcommittee; J. L. Campbell, S. B. Clement, J. M. Farrin, R. J. Herring, H. R. Peterson, E. H. Roth, J. R. Scatterday, H. F. Schryver, B. J. Schwendt, C. K. Smith, C. B. Stanton, R. E. Van Atta, J. S. Worley.

The study undertaken by your subcommittee deals with the economic relation between the track structure and the traffic to be handled. In the past, progressive improvements in the track structure and methods of handling maintenance work have been found necessary to offset the additional burden of heavier wheel loads, higher speeds, increased wages, and decreased revenues.

It is a well known fact that, as traffic density increases maintenance expenses also increase, with certain percentage ratios varying in accord with the particular item in question. As it is also a fact, as will be demonstrated in this report, that maintenance costs per unit of traffic handled are greater in proportion to the inferiority of the track's physical structure, it is evident that the remedy lies in bettering conditions. In any given case, it is obvious that the limit of justifiable additional investment is reached when the extra annual interest and replacement charges exceed the yearly saving that may be obtained.

While it is true that track improvement problems involve consideration of the four essential factors, namely: rail, ties, ballast, and subgrade, for purposes of ready classification, track rating is commonly given in terms of rail weight, for it may be assumed that the quality of the other factors will be such as to provide a balanced structural standard. It is also logical to expect that main track rail and fittings of increased weight will eventually replace the lighter rail in yards and sidings. In other words, the accessory track facilities provided by a railway will be in keeping with its track rating. Hence, it is proper to express traffic density in terms of ton-miles per equated mile in the same manner as section man-hours per equated mile are reported to the Interstate Commerce Commission.

Having thus established a common factor in terms of the equated mile, the direct cost of handling units of traffic in section man-hours may be found. It will be noted that the traffic unit used in Tables A and B, and on Charts 1–8 inclusive, is gross ton-miles per equated mile, and the comparative costs given are in terms of section man-hours per equated mile for each million gross ton-miles per equated mile. The equated mile ratios applied by the Interstate Commerce Commission are: first main track 1.00, additional main tracks 0.80. all other tracks 0.50.

The committee has examined the records of 93 railways reported to the Interstate Commerce Commission and published in the annual reports of the Bureau of Statistics—Series Statement 37.200. The period studied included the years 1927 to 1936, inclusive. Taking the period 1927–8–9 for analysis, it was found that the railways included in the study had definitely classified themselves, through traffic densities attained by that time, into four groups. These groups correspond to four different rail weights, namely: 130-lb., 110-lb., 100-lb. and 90-lb. or less. For the purposes of more modern classification, the groups are designated on the tables and charts of this report, as 131-lb., 112-lb., 100-lb. and 90-lb. or less.

Table A

Comparison Section Man-Hour Per Million Gross Ton-Miles Per Equated Mile Required for Various Weights of Rail

Group	No. of Rwys.	Averages for Years 1927-8-9: Section Man-Hrs. per Eq. Mi. per Annum	Gross Ton-Mi. per Eq. Mi. per Annum	Section Man-Hrs. per Million G.T.M. Per Equated Mi.	Averages for Year 1936: Section Man-Hrs. per Eq. Mi. per Annum	Gross Ton-Mi. per Eq. Mi. per Annum	Section Man-Hrs. per Million G.T.M. Per Equated Mi.
Class							
131-lb.	18	3,035	7,517,761	403.71	1,564	7,296,210	214.36
112-lb.	28	2,362	4,754,770	496.76	1,229	4,199,118	292.68
100-lb.	21	2,103	3,897,706	539.55	1,136	3,427,224	331.46
90-lb.	26	2,196	3,359,940	653.58	1,125	2,700,579	416.58

The result of the analysis is given in Table A, which shows by groups the section man hours per equated mile required per million gross ton-miles per equated mile during the three year period. The same information is shown in this table for the year 1936. The comparative results obtained in the two periods will be discussed later in the report.

It will be noted in Table A, that the section man-hours per million gross tons definitely increase as the rail weight decreases. The record for each of the individual carriers is given in Table B, and the Charts 1 to 8, inclusive, were compiled from the data in this table.

Table B

Section Man Hours Per Million Gross Ton Miles Per Equated Mile Reported by Various Railways

Railway Number and Group	Averages for Years 1927-8-9: Section Man-Hrs. per E. Mi. perq Annum	Gross Ton-Miles per Equated Mile per Day	Section Man-Hrs. per Million G. T. M. per Equated Mi.	Averages for Year 1936: Section Man-Hrs. per Eq. Mi. per Annum	Gross Tons-Miles per Equated Mile per Day	Section Man-Hrs per Million G.T.M. per Equated Mi
131—lb. Group						
No. 1	4,921	16,201	831.30	2,867	16,342	479.34
" 2	4,494	18,256	673.71	1,671	18,289	249.63
" 3	3,866	15,952	663.51	2,316	11,540	548.34
" 4	4,250	20,715	561.68	1,519	18,267	227.20
" 5	3,099	17,259	491.61	1,942	16,869	314.54
" 6	4,348	25,514	466.43	2,318	24,739	256.00
" 7	3,379	20,429	452.74	2,091	19,750	289.27
" 8	2,397	15,048	436.04	1,148	10,079	311.20
" 9	2,850	18,225	428.11	1,323	17,418	207.53
" 10	3,400	22,375	416.06	1,822	23,372	213.00
" 11	2,240	15,194	403.47	1,042	16,229	175.43
" 12	3,011	23,465	351.24	1,484	19,532	207.59
" 13	3,616	26,083	379.38	2,302	26,679	235.75
" 14	3,152	22,816	378.01	1,363	22,124	168.33
" 15	2,674	19,971	366.52	1,780	22,604	215.16
" 16	3,062	23,312	359.40	1,515	20,350	203.41
" 17	3,921	32,474	330.39	2,325	30,124	210.88
" 18	2,133	13,804	422.96	1,153	15,147	207.98
Group Avg.	3,035	20,578	403.71	1,564	19,935	214.36
112—lb. Group						
No. 19	2,692	6,493	1,134.86	1,807	5,393	915.48
" 20	2,275	7,526	827.47	1,372	9,535	393.15
" 21	2,014	6,824	807.76	1,209	6,585	501.64
" 22	2,861	9,911	790.24	1,292	8,821	400.19
" 23	2,852	10,319	756.58	1,475	10,481	384.51
" 24	3,852	15,608	675.55	1,652	11,750	384.14
" 25	2,968	12,549	647.36	2,124	13,780	421.14
" 26	3,447	15,294	616.98	1,827	12,007	415.74
" 27	2,718	11,886	625.93	1,199	10,914	300.16
" 28	2,073	10,114	561.14	2,129	8,702	668.46
" 29	2,877	14,647	537.60	1,953	13,250	402.72
" 30	2,595	13,420	529.38	1,470	12,857	312.39
" 31	2,940	15,481	519.80	1,593	16,775	259.46
" 32	2,245	12,495	491.88	1,272	10,113	343.66
" 33	1,869	10,576	483.67	1,159	8,009	395.39

TABLE B—Continued

SECTION MAN HOURS PER MILLION GROSS TON MILES PER EQUATED MILE REPORTED BY VARIOUS RAILWAYS

Railway Number and Group	Averages for Years 1927-8-9			Averages for Year 1936		
	Section Man-Hrs. per Eq. Mi. per Annum	Gross Ton-Miles per Equated Mile per Day	Section Man-Hrs. per Million G. T. M. per Equated Mi.	Section Man-Hrs. per Eq. Mi. per Annum	Gross Tons-Miles per Equated Mile per Day	Section Man-Hrs. per Million G T.M. per Equated Mi.
" 34	2,447	13,901	481.76	1,302	11,799	301.50
" 35	1,978	11,590	467.25	981	10,435	256.86
" 36	1,664	9,906	459.86	1,036	9,717	291.30
" 37	1,737	10,461	454.38	1,041	9,658	294.50
" 38	2,039	12,323	453.02	1,032	9,415	299.49
" 39	2,775	17,445	435.50	1,170	13,481	237.13
" 40	3,090	20,309	416.34	1,602	18,307	239.09
" 41	1,528	10,103	413.87	687	9,799	191.56
" 42	2,383	15,962	408.67	1,521	12,753	325.86
" 43	1,878	14,945	344.07	1,287	13,424	261.95
" 44	2,688	18,134	405.74	1,315	16,648	215.82
" 45	1,456	12,006	332.03	980	12,352	216.77
" 46	2,265	19,806	313.14	1,514	17,200	240.50
Group Avg.	2,362	13,015	496.76	1,229	11,473	292.68
100-lb. Group						
No. 47	2,097	5,029	1,141.43	1,804	4,977	990.35
" 48	1,582	4,260	1,014.43	1,913	6,387	818.35
" 49	3,607	9,874	999.92	1,671	15,413	296.22
" 50	3,074	9,774	860.87	1,420	10,978	353.41
" 51	1,999	6,491	843.07	1,180	5,204	619.53
" 52	2,272	8,423	738.24	1,612	6,686	658.75
" 53	1,638	6,037	710.86	1,072	5,129	571.06
" 54	2,505	10,592	647.36	1,190	7,352	442.24
" 55	2,094	9,292	616.98	1,121	8,194	373.79
" 56	2,708	12,018	616.70	1,361	11,626	319.85
" 57	2,582	11,458	616.70	1,434	12,800	306.10
" 58	2,065	9,842	574.28	1,566	9,104	469.98
" 59	2,137	10,545	554.84	1,241	9,312	364.12
" 60	3,435	17,077	550.46	1,196	13,762	237.45
" 61	2,171	10,814	549.64	1,239	8,599	393.68
" 62	1,360	7,705	483.12	669	6,031	303.08
" 63	1,182	7,448	434.40	742	5,050	401.45
" 64	1,393	9,131	417.43	744	8,834	230.11
" 65	2,295	16,310	385.13	1,458	15,277	260.76
" 66	1,957	14,413	371.72	1,182	13,425	240.56
" 67	2,286	18,631	338.60	1,224	13,632	245.32
Group Avg.	2,103	10,669	539.55	1,136	9,364	331.43
90-lb. Group						
No. 68	1,724	2,915	1,618.81	1,002	2,489	1,099.92
" 69	1,918	3,703	1,417.90	1,181	3,180	1,014.71
" 70	3,433	6,639	1,415.43	754	3,950	521.55
" 71	1,915	4,219	1,242.44	2,805	4,442	1,725.33
" 72	2,739	6,493	1,188.51	1,787	6,113	798.71
" 73	2,362	6,333	1,020.99	1,352	6,745	547.66
" 74	3,576	12,643	963.25	1,894	11,875	435.78
" 75	1,589	4,511	964.33	1,312	4,375	819.36
" 76	2,928	9,720	824.46	1,498	7,697	531.75
" 77	2,240	7,467	821.18	1,211	7,325	451.71
" 78	2,053	7,304	769.44	1,169	9,738	327.99
" 79	1,594	5,841	747.00	797	4,017	542.10
" 80	1,627	6,288	708.13	672	2,502	733.84
" 81	2,743	11,144	673.64	1,494	9,815	415.89
" 82	2,357	9,829	656.39	1,274	5,997	580.44
" 83	1,328	5,590	650.37	893	3,682	662.65
" 84	2,795	12,362	618.89	1,113	7,179	423.59
" 85	2,437	10,931	610.13	1,319	8,606	418.76
" 86	1,711	8,299	564.42	732	7,093	281.97
" 87	2,051	10,197	550.05	1,020	8,166	341.28
" 88	2,521	12,895	535.13	653	7,003	254.77
" 89	1,938	10,553	501.19	1,309	8,662	412.90
" 90	1,839	10,187	494.07	1,054	7,199	400.03
" 91	2,331	13,003	490.79	408	9,793	113.83
" 92	1,744	9,865	483.95	827	7,430	304.11
" 93	2,447	14,458	463.14	1,236	10,639	317.42
Group Avg.	2,196	9,197	653.58	1,125	7,379	416.58

It should be noted that in calculating the tonnage handled, an average conversion factor of 350 tons was assigned to each passenger locomotive, and 70 tons for each coach, baggage or express car.

The solution of problems involving track betterments is naturally influenced by local conditions on the railway in question, such as lack of available supply of track material on line of road, and procurable only by incurring excess off-line freight charges, ballast and tie timber often coming in this category. Then too, there are differences in assembly details, such as tie sizes and spacing, ballast section preferences, etc. Each problem has to stand on its own merits.

Disregarding the mentioned differences for purposes of general illustration, the committee submits in Table C, a comparative statement of the cost to own and maintain track in each of the four major groups. The investment cost shown is arbitrarily assumed, but the labor charges are taken from Table A. It will be noted that the respective periods 1927–8–9 and 1936 are given in Table C.

Table C

Cost to Own and Maintain Track
1927–8–9

Group	*Investment*	*Interest 5% per Annum*	*Replacements 5% per Annum*	*Section Labor at $0.40 per Hour*	*Total Cost*	*Cost Using Next Lighter Rail*
Class						
131-lb.	$20,200	$1,010	$1,010	$1,214	$3,234	$3,373
112-lb.	18,800	940	940	945	2,825	2,810
100-lb.	17,800	890	890	841	2,621	2,698
90-lb.	16,800	840	840	878	2,558	----
			1936			
Class						
131-lb.	$20,200	$1,010	$1,010	$626	$2,646	$2,738
112-lb.	18,800	940	940	492	2,372	2,336
100-lb.	17,800	890	890	454	2,234	2 252
90-lb.	16,800	840	840	450	2,130	----

Inspection of the costs given in the last two columns of Table C shows that in 1927–8–9 the railways of the 131-lb. and 100-lb. groups, as an average, were justified in using heavier rail, as the cost of handling their respective traffic densities was less than the cost for handling the same traffic over the next lighter section rail. However, the same comparison for the 112-lb. rail does not appear to be so favorable, as the costs for the railways of the 112-lb. group are unfavorable for the heavier rail section. The reason for the unfavorable showing of the 112-lb. Group will be seen from the following analysis of the data given in Table A:

Percentage of Reduction From 1927–8–9 to 1936

Group Lb. per yd.	*Section Man-Hrs. per Equated Mi. Percent*	*Gross Ton-Miles per Equated Mi. Percent*	*Section Man-Hours per Million G.T.M. per Equated Mi. Percent*
131	48.5	2.9	46.9
112	48.0	11.7	41.1
100	46.0	12.1	38.6
90	48.8	19.6	36.3

Examination of the figures discloses that while the heavier weight rail groups effected a slightly greater reduction in section man-hours per equated mile, the advantage is further emphasized by the progressively diminishing results in percentage reduction of section man-hours per million gross ton-miles per equated mile. In short, as weight of rail decreases ability to decrease labor costs also decreases.

From the figures in Table C it would appear that the railways in the 112-lb. group were unable to make sufficient man-hour reductions per equated mile, to permit them to adjust their maintenance costs to proper levels.

Further analysis of the results given in Table A and shown on Charts 1–8 inclusive, very definitely brings out the fact that the reductions in section man-hours from 1927–8–9 to 1936 have not been governed by the use factor values as set forth by former Committee 21, and shown in the Manual, pages 21–9 to 21–14 inclusive.

Referring to Table 2103, page 21–12, it will be noted that Items 6 and 7, Accounts 202 and 220 respectively, are the only figures with which the data in Table A of this report are concerned. It will also be noted that the percent of the sum of those two items of the total M. W. & S. expense is $10.96 + 25.91 = 36.87$ percent of which Account 220 is $\frac{25.91}{36.87} = 70.27$ percent, and referring to the Per Cent Affected by Use column we find that Account 220 is affected by use to the extent of 55 percent, and as Account 202 is not affected at all by use, the percentage affected by use of the sum of the two accounts will be 70.27 percent $\times$ 0.55 = 38.6 percent.

Therefore, if we apply this factor in accordance with the equation shown at the top of page 21–14, we will have the equation—

$$1.00 + (0.3865 \times \text{percent traffic density increase})$$

However, as our comparative analysis of Table A deals only with traffic density decreases, reciprocals must be used.

The formula is given on page 21–14—

$$e = E\left(\frac{1}{1 + \left(\frac{T - t}{t}\right)A}\right)$$

where

e = expense of original base period
E = expense of new base period
t = traffic density of original base
T = traffic density of new base
A = percentage of expenses which are direct at traffic density

applied to each of the four groups on Table A

131-lb. Group, E = 3,010 and Actual Hours Used 1,564
112-lb. Group, E = 2,285 and Actual Hours Used 1,229
100-lb. Group, E = 2,032 and Actual Hours Used 1,136
90-lb. Group, E = 2,076 and Actual Hours Used 1,125

Concerning the foregoing formulas, it should be remembered in preparing the data to be used therein, that the percentages affected by use, as shown in the tables in the Manual, are percentages of retiral causes. They are in no wise affected by the life cycle of the item in question. As an illustration, rail is affected 100 percent by use, that being the sole reason for retiral. Any increase or decrease in the life of rail is reflected directly by an increase or decrease in annual charges.

On the other hand changes in percentages of causes of retiral should be considered. If, for example, untreated ties are replaced by treated ones and they last twice as long, no change is made in the percentage affected by use. However, if larger tie plates are

applied to the ties, reducing mechanical wear and doubling the life, then the percentage affected by use would be reduced by one-half.

In the foregoing tabulation the wide difference between the actual hours worked and the theoretical hours allowed by formula, will at once attract attention. Naturally the question arises. Were these apparent excess reductions in man-hours accomplished by arbitrary curtailment of work to the extent of deferring maintenance?

There can be but little doubt that general business conditions for the last seven years have necessitated the postponement of maintenance work on the railways in general. On the other hand during the past ten years many railways have speeded up their schedules and increased their loads. In such cases it is not logical to presume that any marked impairment of track structure has taken place.

The determination of the extent to which maintenance has been deferred is local to the officers of the individual railway. It would be extremely difficult to determine accurately how the railways, as a whole, have been affected in that respect. However, some rough approximation is possible by comparing the average percentage of reduction in section man-hours of the various groups, with the percentage of reduction made by one of the railways that has accumulated no deferred maintenance. If such comparison were made, using the data given in Table B, it will be noted that the excess percentages of reduction in section man-hours (group averages) over the percentage of reduction given for carrier No. 17, are respectively:

131-lb. = 19.1 percent, 112-lb. = 17.9 percent, 100-lb. = 13.0 percent, 90-lb. = 19.8 percent

As the above percentages are relatively a small part of the total reduction, it is necessary to examine the other contributory factors that permitted the reductions.

Elimination of Non-Essential Work

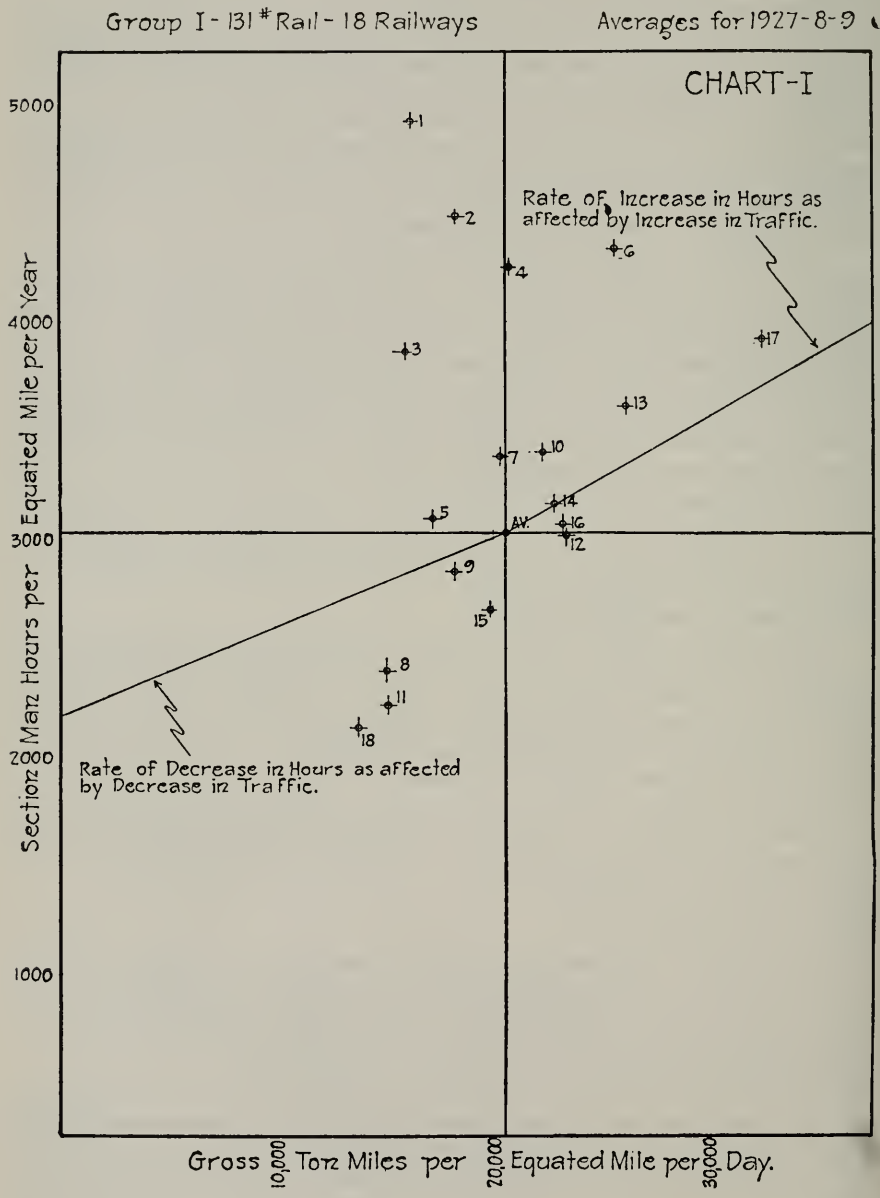
The first step in reducing expense naturally is the elimination of non-essential work, particularly if the items do not affect transportation. Mowing and weeding come in this category. Formerly it was the general practice of the railways to mow the entire right-of-way once, and sometimes twice a year. Now it is the usual practice to mow one swath on each side of the track and this is supplemented by a seasonal burning over the right-of-way. Weeds formerly were laboriously removed by hand; they are now disposed of by burning or chemical treatment.

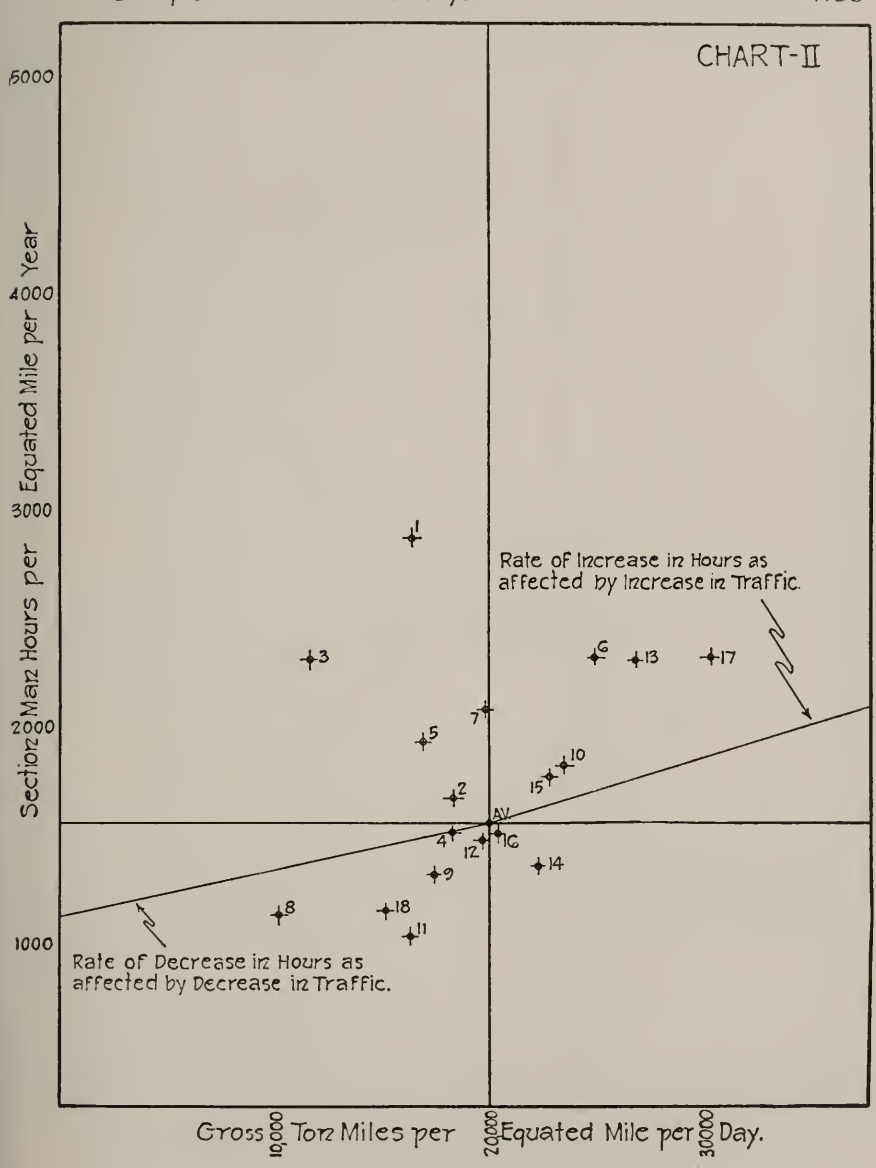
Formerly a great deal of work was done lining up the outside ballast margins and cutting sod lines to improve appearances. This has been discontinued largely as it is not a vital element of maintenance.

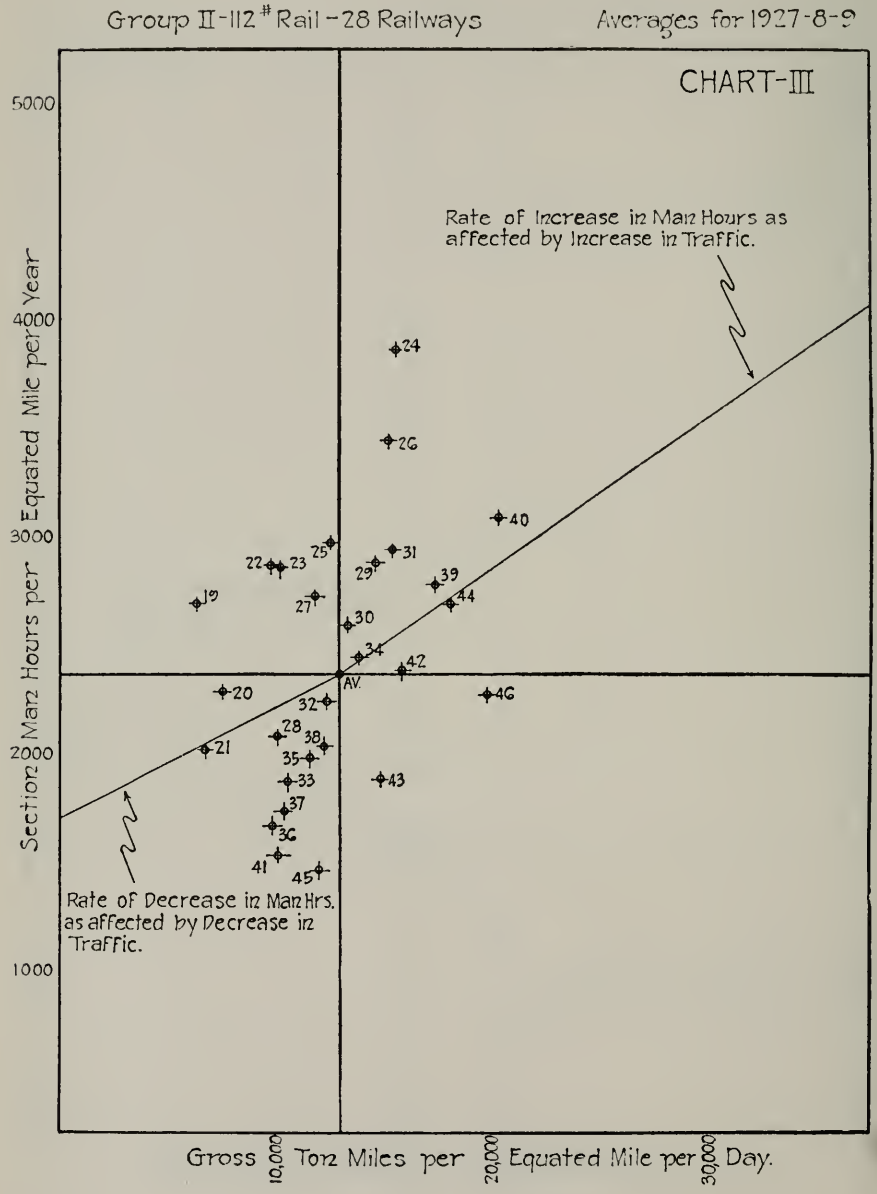
Effect of Track Betterment

The use of heavier rail with larger tie plates, treated ties, deeper ballast, the widening of cuts and fills, providing better drainage, and stabilization of roadbed, not only have permitted changes in organization and methods of handling work that have resulted in substantial man-hour reductions, but these improvements in track structure have greatly increased the safety factor in the conduct of transportation.

Formerly it was the practice of the railroads to patrol track regularly every working day, and in many locations also on Sundays. The necessity for this practice has decreased materially in recent years due to several things in addition to improved track structure. These include the introduction of the detector car for locating transverse fissures, and the great increase in the mileage of automatic signal circuits, which detect broken rails and protect against them. The use of slide detector fences in cuts, as a protection against falling rock, has resulted in the reduction of man-hours for patrolling and watching such locations. Motor cars are used for inspection purposes to a greater


Group I - 131# Rail - 18 Railways
Averages for 1927-8-9
CHART-I
Rate of Increase in Hours as affected by Increase in Traffic.
Rate of Decrease in Hours as affected by Decrease in Traffic.
Section Man Hours per Equated Mile per Year
5000
4000
3000
2000
1000
Av.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Gross Ton Miles per Equated Mile per Day.
10,000
20,000
30,000


Group I - 131# Rail - 18 Railways
1936
CHART-II
5000
4000
3000
2000
1000
Section Man Hours per Equated Mile per Year
Rate of Increase in Hours as affected by Increase in Traffic.
Rate of Decrease in Hours as affected by Decrease in Traffic.
AV.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
10,000
20,000
30,000
Gross Ton Miles per Equated Mile per Day.


Group II-112# Rail - 28 Railways
Averages for 1927-8-9
CHART-III
Rate of Increase in Man Hours as affected by Increase in Traffic.
Rate of Decrease in Man Hrs. as affected by Decrease in Traffic.
Section Man Hours per Equated Mile per Year
5000
4000
3000
2000
1000
10,000
20,000
30,000
Gross Ton Miles per Equated Mile per Day.
AV.
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
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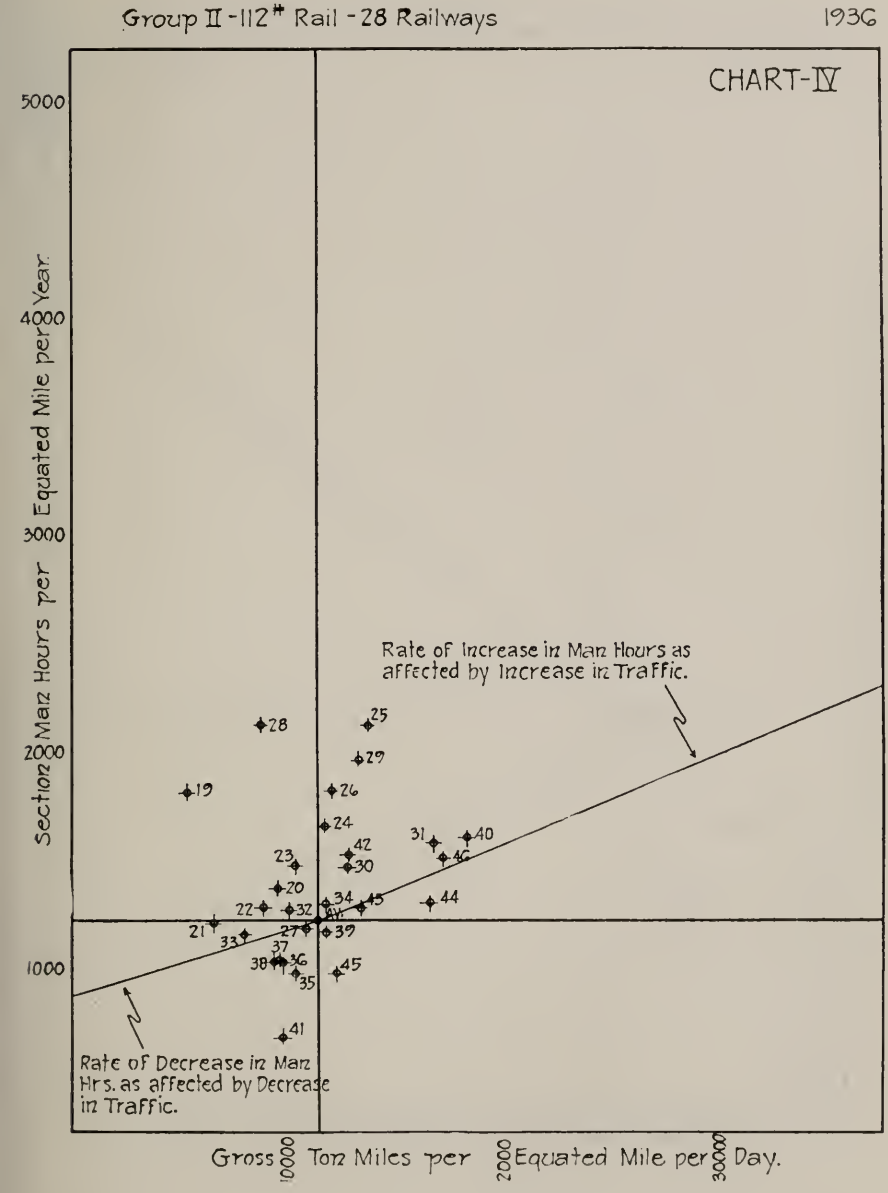
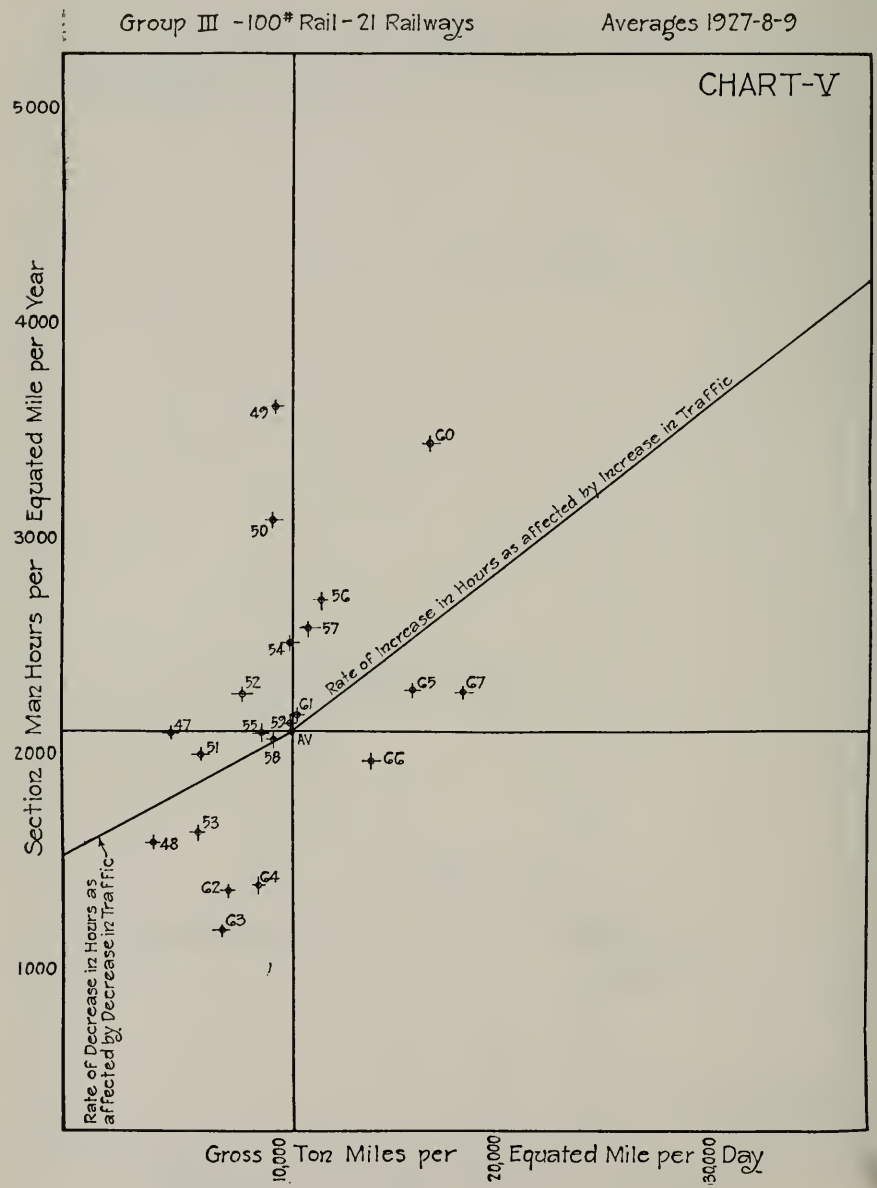
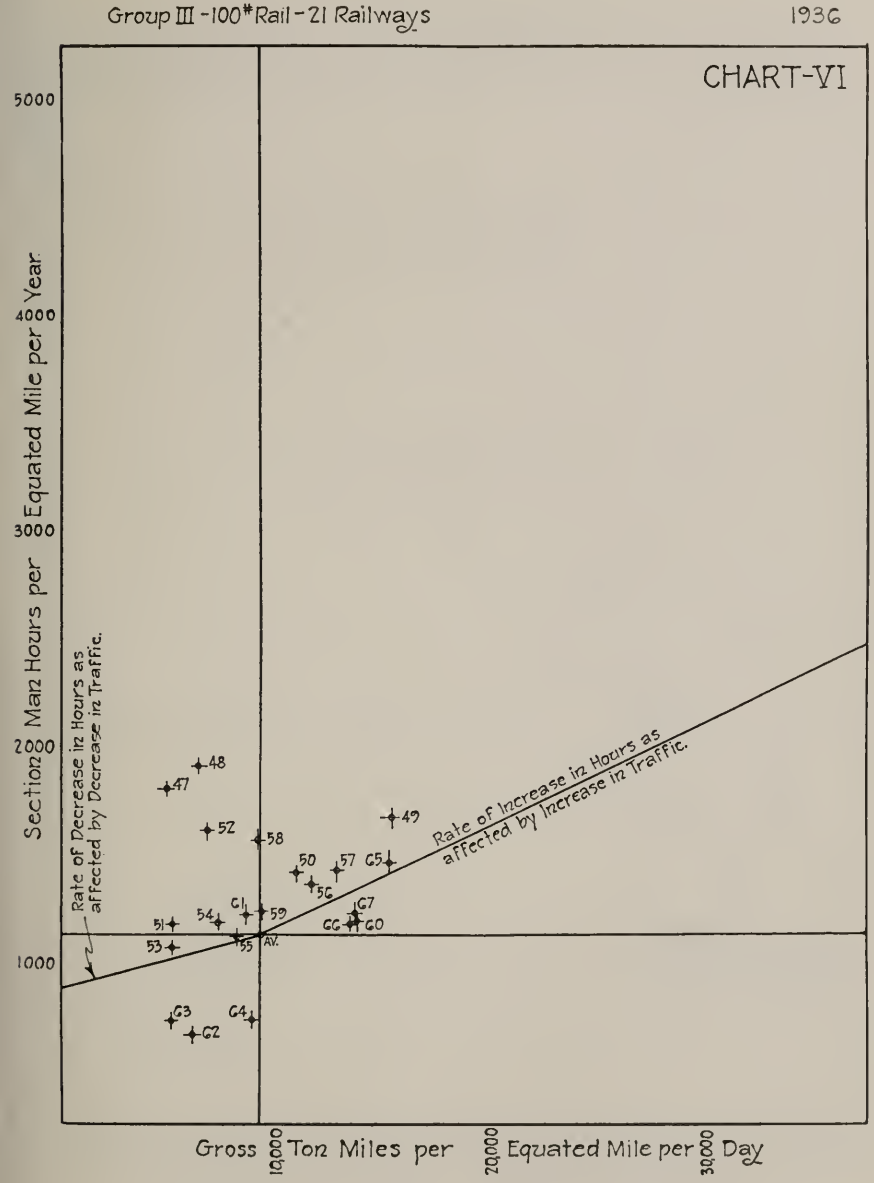
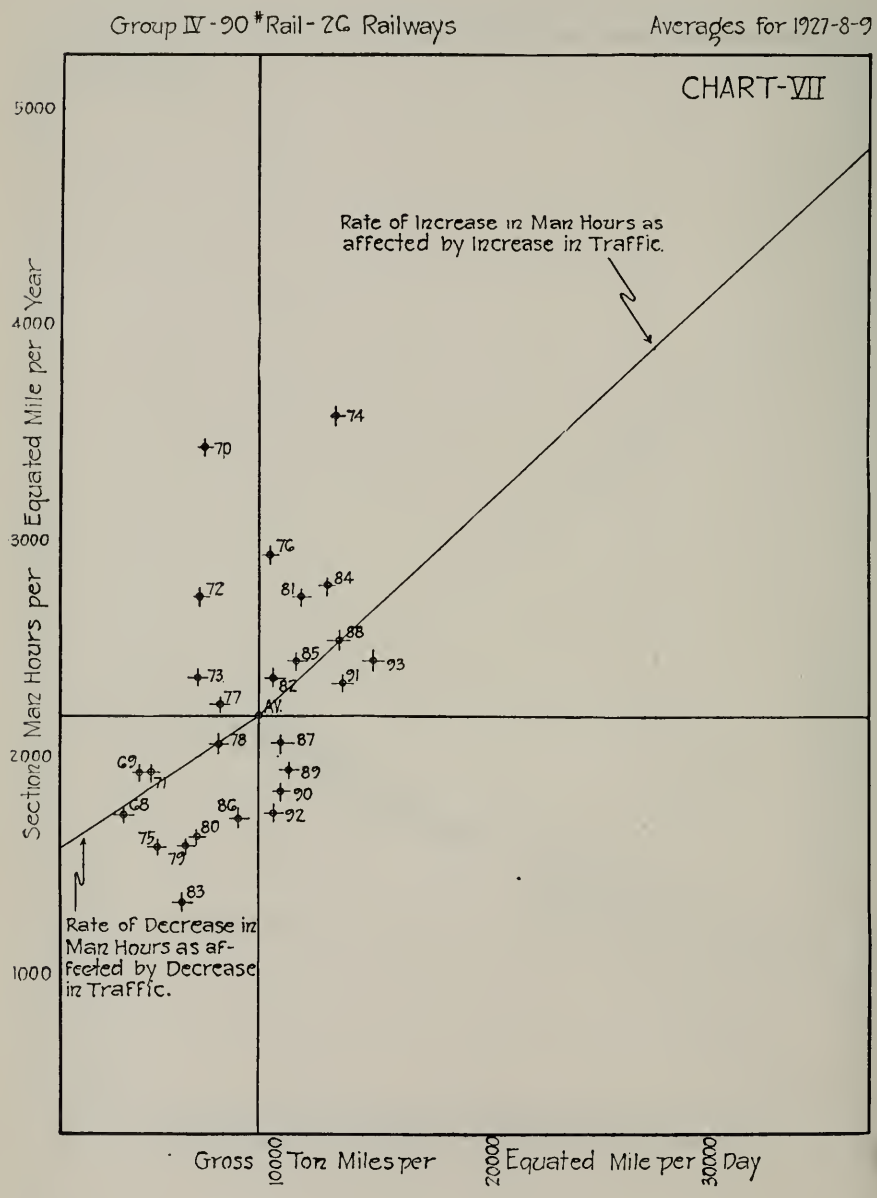
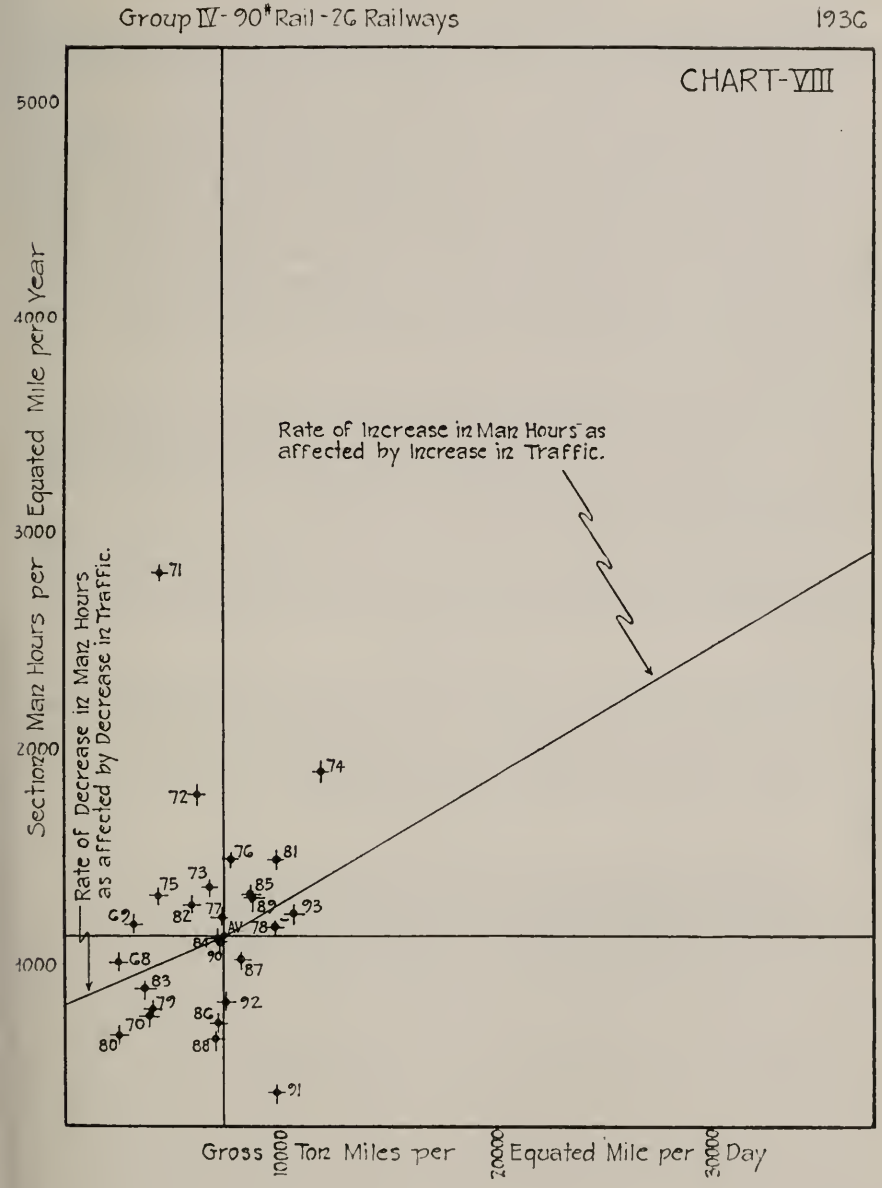
43
44
45
46


Group II - 112# Rail - 28 Railways
1936
CHART-IV
5000
4000
3000
2000
1000
Section Man Hours per Equated Mile per Year
Rate of Increase in Man Hours as affected by Increase in Traffic.
Rate of Decrease in Man Hrs. as affected by Decrease in Traffic.
10000
20000
30000
Gross Ton Miles per Equated Mile per Day.


Group III -100# Rail - 21 Railways
Averages 1927-8-9
CHART-V
5000
4000
3000
2000
1000
Section Man Hours per Equated Mile per Year
Rate of Increase in Hours as affected by Increase in Traffic
Rate of Decrease in Hours as affected by Decrease in Traffic
49
50
56
57
54
52
47
55
53
51
58
AV
61
60
65
67
66
48
53
62
64
63
10,000
20,000
30,000
Gross Ton Miles per Equated Mile per Day


Group III - 100* Rail - 21 Railways
1936
CHART-VI
5000
4000
3000
2000
1000
Section Man Hours per Equated Mile per Year
Rate of Decrease in Hours as affected by Decrease in Traffic.
Rate of Increase in Hours as affected by Increase in Traffic.
48
47
52
58
49
50
57
C5
56
C1
54
59
C7
51
C6
C0
53
55
AV.
G3
G4
G2
10,000
20,000
30,000
Gross Ton Miles per Equated Mile per Day


Group IV - 90 # Rail - 26 Railways
Averages for 1927-8-9
CHART-VII
Rate of Increase in Man Hours as affected by Increase in Traffic.
Rate of Decrease in Man Hours as affected by Decrease in Traffic.
Section Man Hours per Equated Mile per Year
5000
4000
3000
2000
1000
Av.
70
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
69
71
68
Gross Ton Miles per 10000 Equated Mile per 20000 Day
30000


Group IV - 90# Rail - 26 Railways
1936
CHART-VIII
5000
4000
3000
2000
1000
Section Man Hours per Equated Mile per Year
Rate of Increase in Man Hours as affected by Increase in Traffic.
Rate of Decrease in Man Hours as affected by Decrease in Traffic.
71
74
72
76
81
73
75
85
77
82
89
93
78
AV
84
90
68
87
83
79
92
86
70
80
88
91
10000
20000
30000
Gross Ton Miles per Equated Mile per Day

extent than formerly, and with their greater mobility, as compared with the hand-operated lever cars, it has been possible to lengthen sections and, coincidentally, decrease travel time.

The track motor car is by no means the only agency that has been employed in reducing travel time. The use of highway automotive vehicles for transporting men and materials in congested metropolitan districts has been of distinct benefit.

The heavier maintenance work is now performed by specially organized gangs provided with the mechanical equipment adapted to handling heavier material or improving the quality of work. However, the effect of mechanization should not be over stressed. A recent investigation of the records of two of the most thoroughly mechanized railways in the country, discloses the fact that a comparison of the operations performed in 1937 with those of 1915, when there was practically no mechanical equipment in use, showed that only 3.5 percent of the total M. of W. & S. expenditures had been affected by the use of machinery. It was also found, in comparing the same two years, that the expenditures for roadway—track laying and surfacing labor had been affected to the extent of 7.5 percent.

Another factor that should not be overlooked, in any analysis of track economics, is the effect of increased train lengths. The natural result of this is to decrease the number of trains, thereby increasing the intervals between, permitting longer periods for productive work and less loss for stand-by labor. This is also true in the case of off-track work equipment of the heavier types, such as tractor cranes, etc.

Reviewing the various items that have been discussed, in connection with the reduction in hours required for track laying and surfacing, it is evident that there is a wide range for variation in the contributory factors in any given case, and that any effective analysis of an individual railroad's results is peculiar to the railway in question.

Conclusion

That there is a definite economic relation between track structure and traffic density.

That justification for improvements in track structure to meet increased traffic density should satisfy the requirements of the following formula—

$$\frac{c_1 + c_2}{t} \text{ is greater than } \frac{C_1 + C_2}{T}$$

where

c_1 = Cost to own one mile of original base track per annum
c_2 = Cost to maintain one equated mile of original base track per annum
t = G.T.M. per equated mile of base traffic per annum
C_1 = Cost to own one mile of proposed track per annum
C_2 = Cost to maintain one equated mile of proposed track per annum
T = G.T.M. per equated mile of new traffic per annum

It is recommended that this report be received as information.

Appendix D

(4) THE EFFECT OF VOLUME OF TRAFFIC ON RAILWAY OPERATING EXPENSES

S. W. Fairweather, Chairman, Subcommittee; J. A. Anderson, V. T. Boughton, Richard Brooke, S. B. Clement, J. H. Dyer, G. W. Hand, R. J. Herring, F. R. Layng, J. A. Parant, H. R. Peterson, C. P. Richmond, B. J. Schwendt.

The subject of this report was first assigned to former Committee 21, in 1931, and reports were submitted to the conventions in 1932, 1934, 1936 and 1937. These were received without discussion, and were published in the Proceedings, Vol. 33, p. 205; Vol. 35, pp. 910–922; Vol. 37, pp. 544–548; and Vol. 38, pp. 403–408, respectively.

In these previous reports consideration was given to the analysis of statistical data applicable to Class I railroads of the United States with reference to factors underlying fluctuations of operating expenses that have a casual relation to traffic density, while tables, diagrams, equations and examples were presented showing the methods used to determine the effects of traffic density on operating expenses. Tables were given showing "proportion variable of transportation expense" at indicated levels of traffic density corresponding with the three districts of Class I railroads. And, finally, in the last report, by means of equations and charts, a simplified method of arriving at the effect of traffic density on operating expenses was developed.

Further study of the subject is being pursued by the committee and a report completing the exposition, the discussion of all factors involved, and the presentation of concise conclusions is planned.

It is recommended that this review of the work done be received as information.

APPENDIX E

(6) EFFECT OF INLAND WATERWAY TRANSPORTATION ON THE ECONOMICS OF RAILWAY OPERATION

J. E. Teal, Chairman, Subcommittee; Richard Brooke, Olive W. Dennis, H. H. Edgerton, R. P. Forsberg, G. D. Hughey, E. E. King, Fred Lavis, Wm. Michel, F. A. Russell, C. K. Smith, R. E. Van Atta, S. L. Wonson, J. S. Worley.

Foreword

This is a new subject, concerning which your committee proposes to present a number of reports, the first of which comprises a brief history of the development of inland water transportation in the United States as related to the development of railway transportation. No credit is claimed for originality; however, it may contain information of interest to many members of the Association who are not informed as to what is transpiring in the field of waterway transportation. In subsequent reports an effort will be made to analyze specific inland waterway projects and determine, if possible, their economic values, including the volume and cost of handling traffic as compared with rail traffic. It is proposed, also to evaluate, if possible, the effect of the loss of rail traffic to the waterways.

A large library on this and related subjects has been accumulated by the chairman of the subcommittee. However, for the purpose of this and succeeding reports, the work of the Bureau of Railway Economics entitled "An Economic Survey of Inland Waterway Transportation in the United States," special series No. 56, published in Washington in 1930, and "The American Transportation Problem," prepared for the National Trans-

portation Committee by Harold G. Moulton and associates, published by the Brookings Institution in Washington in 1933, will be used as a text; and, when available, statistical data will be brought up to date. Also, use is made of material contained in article "Water Transportation versus Rail Transportation: A Symposium" by C. D. Bordelon, —Proceedings, ASCE, Vol. 64, No. 1, p. 189, and many references will be made to other papers and discussions and articles that have been published from time to time.

Brief History of River and Canal Transportation

Rivers and canals were among the principal channels of transportation in the United States until the close of the Civil War. In Virginia, the James River Company, which had as its object the construction of a canal from the tidal basin of the James river at Richmond, Va., following the James to Clifton Forge, Va., and crossing the Alleghany mountains to the Kanawha river (a tributary of the Ohio) in West Virginia, was organized by George Washington and others, as a stock company, in 1785. This canal was completed from Richmond, Va., to Buchanan, a distance of 200 miles, and, later, the property was taken over by the predecessor of the Chesapeake & Ohio Railway Company. In 1825, the Erie canal had been completed between the Hudson river and Lake Erie, 351 miles, and the Chesapeake and Ohio canal was in operation between the tidal basin of the Potomac at Washington, D. C., 185 miles, following the Potomac river to Cumberland, Md.

The construction of canals spread very rapidly, not only in those states along the eastern seaboard which were in need of lines of communication with the middle west, but canals were also constructed within the western states. By 1838, indebtedness had been incurred by 18 states to the extent of $60,201,551 for canals, $42,871,084 for railways, and $6,618,868 for public roads.[1]

The development of railways after 1865 gradually attracted much of the commerce formerly moved by water, besides creating new commerce in many directions not served by rivers; following which, the rivers and canals declined to a condition of little importance.

The first turnpike roads were built in the United States as toll roads, and, likewise, the early canals were built with the view that the full cost of transportation should be borne by the shipper. Accordingly, tolls were levied for the use of property constructed and maintained by private capital and by the states. Few, if any, of the canals, however, yielded returns sufficient to cover both capital charges and maintenance expenses. The panic of 1837 and the following depression definitely eliminated the idea of deriving large financial revenues from state canal systems. The Pennsylvania canals proved a complete financial failure. Almost the entire system was sold to railroad companies in 1857 and 1858, the net loss to the state being put at $59,440,078.[2]

The New York system of inland waterways, which includes the Hudson River and Erie and Champlain Canal, made a better showing, but had, and still has, to be supported in substantial part by general taxation. The taxpayers had contributed $33,500,000 up to September 30, 1882, and a total of $73,000,000 up to September 30, 1902. The net cost to the taxpayers since then has aggregated $273,000,000, making a total cost of canals to the people of New York from the beginning, down to 1929, of more than $346,000,000.[3]

It may be said that the canal system of the United States reached its high point of development between 1850 and 1860. In specific cases, however, the peak of traffic was

[1] "The American Transportation Problem," page 430.
[2] "The American Transportation Problem," page 430.
[3] "An Economic Survey of Inland Waterway Transportation in the United States," page 152.

reached much later. The New York canal system carried its greatest traffic in 1872, and the Illinois and Michigan canal, in 1882.

Canal abandonments began before the Civil War, the aggregate being 314 miles by the close of 1860. In summarizing the condition of the canals in 1880, the census of the United States indicated that 1957 miles had been abandoned, and a large portion of the remaining mileage—i.e., 2,515 miles—was not paying expenses.[4]

The advent of the steamboat ushered in a program of deepening and improving river channels. Prior to the beginning of the nineteenth century, river commerce was handled by canoes, keel boats, and barges, and river obstructions were unimportant. Robert Fulton made his first test of steam transportation on the Hudson River in 1807, when he ran the "Clermont" from New York to Albany. The steamboat soon moved west, when the first regular steamboat service was established on the Mississippi by Fulton and Livingston in 1817, and, three years later, a survey was authorized by Congress to determine the most practicable method of improving the Ohio and Mississippi rivers for navigation purposes. No less than 79 steamboats were operated between Pittsburgh and St. Louis at this time. In 1824, a federal appropriation for river improvements of $75,000 was made. During the next 50 years, these appropriations remained comparatively unimportant, as only approximately $16.500,000 had been appropriated for improvements on the Mississippi river and tributaries as of 1879.[5]

The operation of steamboats did not drive the flat boats and barges off the rivers, and the number of arrivals of this class of craft at New Orleans continued to mount until 1847, but decined thereafter. On the other hand, steamboat traffic continued to increase. Steamer arrivals at New Orleans, according to government statistics, steadily increased from 21 in 1813–14 to 3,566 in 1859–60, when the Civil War put an end to commercial activities. The commerce of New Orleans increased with the expanding settlement of the sections served by the Mississippi River system, to the beginning of the War, in 1861, the value of receipts having increased from $3,500,000 in 1801 to $185,000,000 in 1860.

The peak of river transportation was reached about the same time as the peak of canal transportation. Practically no transportation agencies were competing with the Ohio and Mississippi river carriers until after 1850. New Orleans was the fourth port in the world in 1840, and the river communities of St. Louis and Cincinnati continued to be much greater in population and much more important commercially than Chicago, until after the Civil War, when the railways became real competitors for the traffic handled on the rivers.

By 1885 the river carriers had lost most of the high-grade traffic. However, low-grade traffic such as sand and gravel and coal continued to move in fairly large quantities for a longer period. By the end of the century, with the exception of coal traffic on the Monongahela and Ohio rivers, canal and river transportation had come to be relatively unimportant.

The Effect of the Railway on River and Canal Transportation

As indicated on pages 34 to 39 inclusive, of "An Economic Survey of Inland Waterway Transportation in the United States," the coming of the railways had a profound influence on the growth of river and canal transportation. The following paragraphs have been extracted from this document.

[4] "The American Transportation Problem," page 431.
[5] "The American Transportation Problem," page 432.

From the beginning of railway construction in the United States, about 1830, a new element entered the field to compete with river and canal transport agencies. This development was first noted in the East, where railway construction began.

Railway building in the West began in the decade from 1840 to 1850, when numbers of short and disconnected lines were constructed as feeders to the waterways. Water and rail connections were thus created down the Ohio and Mississippi rivers, and as far north as La Crosse, Wis., on the upper river. Other junction points were established on the Missouri, Cumberland and Tennessee rivers.

These short lines, connecting interior communities with waterways, were intended to supplement, rather than to compete with, the waterways. But economic conditions soon placed the railways in the position of direct competitors with waterways. The disruption of river traffic during the Civil War was a contributing factor in the decline of water transport.

The connection made by rail between Lake Erie and the Ohio river in 1848, and the addition of a second line in 1851, tended more and more to divert traffic northward to the Lakes and thence to eastern markets, thus avoiding the long coastal water journey along the Atlantic seaboard.

Meanwhile the railways on the seaboard began pushing westward, their prompter and more reliable service drawing away still more of the river traffic, and the same situation was developing more slowly through the South.

When enabling legislation was enacted by Congress to permit the building of railway bridges, in the face of opposition from waterway interests, the railways were able to continue their extensions west and south, [thus assuring through transportation by rail to and from the eastern seaboard and further adversely affecting river and canal traffic].

The year immediately preceding the Civil War, 1859–60, was the best ever recorded for the river traffic to New Orleans. At the same time, rail traffic was growing steadily, and, after the close of the war, river and rail movement pursued differing tendencies, one downward and the other upward. A table of the value of receipts at New Orleans during the period from 1872 to 1887, for example, shows that receipts by river fell from $144,000,000 to $59,000,000, while receipts by rail and canal increased from $44,000,000 to $105,000,000.

Other rail movements were also growing. Eastward rail shipments of grain and flour from Chicago, which were negligible prior to 1840, reached 10,000 bushels in that year, and grew apace thereafter. The total reached 1,859,000 bushels in 1850, 31,109,000 bushels in 1860, and 54,742,000 bushels in 1863

The hiatus in Mississippi transportation caused by the Civil War was never completely closed, and the war may be considered as one of the historical causes of the decline of water transport. A more fundamental factor was the continued growth of the railway network and the inability of the older methods of river and canal transportation to compete, on an economic basis, with the steam railway.

Some traffic in favored situations, such as that on the Monongahela, grew quite steadily; but the great majority of the other once important streams, and the Mississippi itself, retired to a condition of comparative commercial quietude, from the outbreak of the Civil War to that of the World War in 1914.

President Hoover (address at Louisville, October 23, 1929), described this decline in picturesque language when, speaking of the old river steamboats, he said: "In time they were unable to compete with the spreading railroads, and river navigation passed into its Dark Ages."[6]

Table I shows the development of railway mileage by decades from a small beginning of 23 miles in 1830 to the present time. It will be noted that the period of most rapid development followed 1860, when only 30,626 miles had been constructed. This mileage had been tripled by 1880, and it reached a peak in 1916, with 254,251 miles, and declined to about 239,112 miles at the end of 1937, or 15,139 less than in 1916.

[6] "An Economic Survey of Inland Waterway Transportation in the United States," page 36.

Table I

Growth of Railway Mileage in United States

1830	23	1910	240,293
1840	2,818	1916	254,251
1850	9,021	1920	252,845
1860	30,626	1930	249,052
1870	52,922	1935	241,822
1880	93,627	1936	240,104
1890	163,605	1937	239,112
1900	193,346		

The railway development between 1860 and 1880, of course, accounts for the reduction in canal mileage during that period. Unfair competition offered by the railways was thought to be the reason for the decline of water transportation. To meet such competition, the tolls of waterways that were charged to cover interest and maintenance charges were steadily reduced, and finally abolished during the decade ended with 1890. The federal government had a less prominent part than the states in the development of inland waterways, the aggregate federal expenditure to 1890 being approximately $100,000,000 for river and canal improvements, while that of the states amounted to approximately $200,000,000.[7]

RENAISSANCE OF RIVER AND CANAL TRANSPORTATION

The inland waterways renaissance began in the last decade of the nineteenth century. It received a great stimulus during the World War, and since the war has been carried forward with the assistance of fostering legislation and the support of many government officials, individuals and organizations.

At this time the railways had practically supplanted inland waterway carriers, and from time to time the capacity of the railroads was overtaxed. In 1895 the International Waterways Convention was held in Cleveland, Ohio, and some five years later, the first national Rivers and Harbors Congress was held in Baltimore, Md. The influence exerted by these two conventions, together with that of various commercial organizations, created new interest in waterway transportation. Congress passed a Rivers and Harbors Act in 1902, which provided for the establishment of a Board of Army Engineers to review all recommendations for inland waterway projects.

The people of New York voted $101,000,000 for the improvement of the Erie Canal in 1903. The Inland Waterways Commission was appointed in 1907 by President Theodore Roosevelt, which was succeeded by the National Waterways Commission on March 3, 1909. The preliminary report of the Inland Waterways Commission in 1908 contains the following statement:

> "While the railways of mainland United States have been notably efficient in extending and promoting the production of commerce of the country, it is clear that at seasons, recurring with increasing frequency, they are unable to keep pace with production or to meet the requirements of transportation."

The commission further stated that, although navigation of the inland waterways had declined with the increase in rail transportation during the latter decades of the nineteenth century, it was clear that the time had arrived for restoring and developing such inland navigation and water transportation to be utilized as a necessary adjunct to rail transportation commensurate with the benefits and cost thereof.

[7] "The American Transportation Problem," page 434.

> "While trustworthy estimates cannot be made without further data," said the committee, "it is reasonable to anticipate that congestion of interstate commerce can be obviated in a large measure by judicious improvement of waterways adapted to barge and boat traffic, at a figure much less than estimated by competent authorities for so increasing railway facilities as to meet present needs."

Following the recommendation of the committee, the President, as a result of Act of Congress dated March 3, 1909, appointed the National Waterways Commission, composed of 12 members of the Senate and House of Representatives, to bring into co-ordination the Corps of Engineers of the Army, the Bureau of Soils, the Forest Service, and other branches of public service, in so far as their work related to inland waterways, for the purpose of making further investigations of various kinds.[8]

The final report of this commission was presented in 1912, and it pointed out that some of the economic factors previously considered as unfavorable to the development of water transportation were gradually changing. These factors included the rapid increase in population, the rapid industrial development of the country, and the greatly increased value of agricultural products. During the first decade of the twentieth century the movement of traffic had increased out of all proportion to the increase in transportation facilities. During this period railway mileage increased about 36 percent, the number of locomotives and freight cars, 56 percent, while the traffic, measured by ton-miles of service, increased 80 percent. Previous to this period the situation was reversed; the increase of railway facilities had been greater than the increase in traffic. With the rapid expansion in business, the car shortages of 1906 and 1907 caused a great amount of complaint and dissatisfaction, and substantiated the belief that the railways were inadequate to meet the inland transportation requirements of the nation.

This thought continued during the period up to the beginning of the World War in 1914. The enormous increase in traffic undoubtedly caused the existing railroad plant to become congested, and water transportation was partly taken over by the government as a means to supplement existing services.

Major General T. Q. Ashburn also corroborated this understanding in his testimony in March, 1935, before the joint committee of the Senate and House when considering a bill to regulate water carriers. The general stated in part: "Please remember that the rehabilitation of our interior waterways commerce began with the crying need of our interior communications systems for more and better means of supplying the needs of our recruits at home and overseas."

The experience during the World War period led to the profound belief in many quarters that the railroads of the nation would never be able to take care of the transport needs of the country but would have to be supplemented by the inland waterways, and this sentiment prevailed prior to the enormous development and expansion of our present highway system. This belief was repeatedly expressed by many of recognized authority. It will be noted, therefore, that the belief in the need of greater development of the inland waterways can be definitely fixed at the time when the traffic offered the railways was greater than they could satisfactorily handle.

Changed Conditions Since the World War

After the World War, the conditions affecting the capacity of the railways to handle traffic were materially changed. The railways increased their capital investment from $20,467,000,000 to $26,355,000,000 between 1920 and 1930, amounting to an increase of 29 per cent. The peak of railway traffic was reached in 1929, when more than

[8] C. D. Bordelon—Proceedings, ASCE, Vol. 64, No. 1, p. 190.

447,000,000,000 revenue ton-miles was handled with no car shortage. This compares with a traffic volume of 410,000,000,000 revenue ton-miles in 1920, during which year there was a reported maximum shortage of 147,309 cars.

This increased capacity of the railways is the result of a plan of expansion adopted by the managements shortly after the end of federal control. It was early in 1923 when the railway executives agreed upon this program, looking forward to the rehabilitation of plant facilities and to more economical operation. During the eight years ended with December 31, 1930, some $6,000,000,000 had been expended, the investment at the end of the period being $26,354,686,000. The idea was to supply the nation with the best transport facilities in the world, and to assure the public that it need not worry for the lack of efficient a..d economically operated transport facilities in the future.

Mr. Herbert Hoover, as secretary of commerce from 1921 to 1928, and, later, as President of the United States, was a strong advocate of waterway development in this country. While secretary of commerce, he made a number of addresses and reports urging waterway development on a national scale. In 1929, as President, Mr. Hoover formulated a definite program and proposed it as one of the things for which his administration would strive.

At Louisville, Ky., on October 23, 1929, Mr. Hoover officiated at the celebration of the completion of the 9-foot channel of the Ohio river from Pittsburgh, Pa., to Cairo, Ill. In his address on this occasion, he outlined eight principal items covering a coordinated inland waterway system as "the policies of my administration," which are quoted below:[9]

> "1. As a general and broad policy I favor modernizing of every part of our waterways which will show economic justification in aid of our farmers and industries.
>
> "2. The Mississippi system comprises over 9,000 miles of navigable streams. I find that about 2,200 miles have now been modernized to 9 ft. in depth, and about 1,400 miles have been modernized to at least 6 ft. in depth. Therefore some 5,000 miles are yet to be connected or completed so as to be of purpose [use] to modern commerce. We should establish a 9-foot depth in the trunk system. While it is desirable that some of the tributaries be made accessible to traffic at six or seven feet, yet we should in the long view look forward to increasing this latter depth as fast as traffic justifies it.
>
> "This administration will insist upon building these waterways as we would build any other transportation system—that is, by extending its ramifications solidly outward from the main trunk lines. Substantial traffic or public service cannot be developed upon a patchwork of disconnected local improvements and intermediate segments. Such patchwork has in past years been the sink of hundreds of millions of public money.
>
> "3. We must design our policies so as to establish private enterprise in substitution for government operation of the barges and craft upon these waterways. We must continue government barge lines through the pioneering stages, but we must look forward to private initiative not only as the cheapest method of operation but as the only way to assured and adequate public service.
>
> "4. We should complete the entire Mississippi system within the next five years. We shall then have built a great north and south trunk waterway entirely across our country from the Gulf to the northern boundaries, and a great east and west route, half-way across the United States. Through the tributaries we shall have created a network of transportation. We shall then have brought a dozen great cities into direct communication by water; we shall have opened cheaper transportation of primary goods to the farmers and manufacturers of over a score of states.
>
> "5. At the present time we have completed 746 miles of intracoastal canals. We still have approximately 1,000 miles to build. We should complete this program over a period of less than ten years.

[9] "An Economic Survey of Inland Waterway Transportation in the United States," page 84.

"6. We should continue improvement of the channels in the Great Lakes; we should determine and construct those works necessary for stabilizing the lake levels.

"7. One of the most vital improvements to transportation on the North American continent is the removal of the obstacles in the St. Lawrence river to ocean-going vessels inward to the Great Lakes. Our nation should undertake to do its part whenever our Canadian friends have overcome those difficulties which lie in the path of their making similar undertakings. I may say that I have seen a statement published lately that this improvement would cost such a huge sum as to make it entirely uneconomical and prohibitive. To that I may answer that after we have disposed of the electrical power we could contract the entire construction for less than $200,000,000, divided between the two governments and spread over a period of ten years.

"8. With the increasing size of ocean-going vessels and the constantly expanding volume of our commerce, we must maintain unceasing development of our harbors and the littoral waterways which extend inland from them."

President Hoover's annual message to Congress dated December 3, 1929, contained the following statements, comments, and recommendations about waterways:

"The development of inland waterways has received new impulse from the completion during this year of the canalization of the Ohio to a uniform nine-foot depth. The development of the other segments of the Mississippi system should be expedited. * * *."

"Expansion of our intracoastal waterways to effective barge depths is well warranted. We are awaiting the action of Canada upon the St. Lawrence waterway project."

The Hoover inland waterways policies with respect to river and canal improvements and construction embraced the following items:

1. Further development of the Mississippi–Ohio system;
2. Development of a system of intracoastal canals;
3. Construction of the St. Lawrence ship channel.

President Roosevelt has supported the inland waterways policies advocated by Mr. Hoover to the fullest extent. As recently as August 18, 1938, at Kingston, Ont., Mr. Roosevelt took occasion to answer arguments that development of the St. Lawrence waterway would hurt the railroads. He said:

"We know now that the effect of a waterway is not to take traffic away from railroad lines. Actually, it creates new possibilities, new business, new activities. Such a waterway generates more railroad traffic than it takes away."

This is a statement of which no proof is presented, and is probably inaccurate. We shall revert to this in future reports, in which an analysis of the traffic created and transported will be made, and the economic justification of a number of inland waterway projects will be studied by your committee, which will include the following:

1. The Inland Waterways Corporation;
2. The Ohio river and tributaries;
3. The Upper Mississippi river;
4. The Lower Mississippi river;
5. The Warrior river;
6. The Missouri river;
7. The Intracoastal waterways;
8. The proposed St. Lawrence River deep waterway;
9. The New York State barge canal;
10. Co-ordination of water and rail service;
11. The proposed Canal Connecting Lake Erie with the Ohio river;
12. Illinois River–Chicago Drainage canal.

In a report of March 10, 1934, Joseph B. Eastman, federal co-ordinator of transportation, made a statement that from 1920 to 1932 the net total expenditures for new transport facilities amounted to $19,110,000,000, which was substantially the same as the railway investment at the beginning of that period. Included in that sum was an investment of $423,613,000 in pipe lines for the transportation of gas and petroleum products, $12,500,000,000 for highways and $604,000,000 of federal money for the improvement of rivers and harbors.[10]

It is evident that the Nation's transport facilities at the present time have been expanded to a point far beyond the requirements. From this, combined with the fact that the physical expansion of the country has been largely accomplished, it is apparent that there is no economic justification for the continued spending of millions of dollars by the federal government yearly on the inland waterways to supplement land transportation facilities.

The government program of inland waterway development, however, is far from complete. In fact, unless the present plans are changed, their execution will involve expenditures over the next several years aggregating many millions of dollars. Authorized expenditures as reported by the Chief of Engineers, United States Army in 1937, and shown on Table 2, amount to more than $1,030,000,000 on the Mississippi and Ohio systems, and nearly $287,000,000 on the intracoastal canals and other waterways. Of these authorized expenditures, some $187,000,000 is yet to be expended. The program calls for canalization not only of so-called trunk line waterways, such as the Ohio and Mississippi systems, but also of the branch and sub-branches thereof, together with a large number of other separate projects. It would be impracticable for this committee to give a complete list of waterway improvements now being made by the federal government; however, the report of the Chief of Engineers, United States Army, 1937, shows, as of October 15, 1937, allocation of funds to river and harbor projects under the Public Works and Emergency Relief programs aggregating $380,970,000, covering a total of 137 items, located at different points in the United States and its possessions.

Table 2

Federal Expenditures as of June 30, 1937[11]

Mississippi–Ohio System—		
Cost of New Work*	$689,228,287	
Maint., Operation, etc.*	206,222,256	$895,450,543
Unexpended balance available	$ 39,960,972	
Additional amount required to complete	95,127,000	135,087,972
Total		$1,030,538,515
Intracoastal Canals and Other Waterways:		
Cost of New Work*	$176,984,490	
Maint., Operation, etc.*	57,836,384	$ 234,820,874
Unexpended Balance Available	$ 13,658,898	
Additional Amount Required to Complete	38,437,000	52,095,898
Total		$ 286,916,772
Grand Total		$1,317,455,287

Note: * Includes value of plant, stocks and undistributed items proportional to cost of new work and maintenance and operation.

[10] C. D. Bordelon—Proceedings, ASCE, Vol. 64, No. 1, p. 195.

[11] Report of the Chief of Engineers, U. S. Army, 1937, Part 1, page 18. Includes amounts actually expended under the direction of the Chief of Engineers in connection with the maintenance and improvement of rivers and canals for navigation and flood control.

Reports on 150 preliminary examinations and surveys, and 116 reviews of previous reports requested by Congressional committees were submitted to Congress during the fiscal year ended June 30, 1937. A total of 187 of the 200 investigations authorized under the provisions of House document No. 308, Sixty-ninth Congress, first session, have been transmitted to Congress. The supplemental investigations authorized in Section 6 of the River and Harbor Act of August 30, 1935, have been placed under way on a number of streams. Section 4 of the River and Harbor Act approved August 26, 1937, provides for 161 preliminary examinations and surveys.[12]

The Board of Engineers for Rivers and Harbors was created under an act of Congress in 1902 and subsequent acts, and described in the Annual Report of the Chief of Engineers, United States Army of 1922. One of the duties of this board is to review, from an engineering standpoint, all recommendations for waterway projects. The work accomplished by the board during the fiscal year ended June 30, 1937, and the status of its operations from its organization up to the close of the fiscal year are as follows:[13]

Total number of investigations ordered	4,853
Total number of investigations completed at the close of the preceding fiscal year	4,119
Number completed during the year ended June 30, 1937	207
Number remaining to be completed	527
Estimated cost of projects recommended by the board from its organization to June 30, 1937	$1,133,104,934
Estimated cost of projects so recommended adopted by Congress	1,048,892,858

Effect of River and Canal Transportation on Railway Operation

A study of the effect of the development of inland waterway transportation, as now planned, on the economics of railway operation—that is to say, on the general business of freight transportation by railways—requires a survey of the financial and economic conditions under which these recent developments of the waterways have been and are being carried out. The scope of the survey, while broad enough to include waterway transportation on the Great Lakes and on the intracoastal canals and connecting channels, will be largely confined to the rivers and canals. A document issued by the United States Department of Commerce, domestic commerce series No. 32, in 1930, reporting on inland waterway transportation, omitted the Great Lakes, stating, "Transportation on the Great Lakes more nearly approaches ocean transportation and should be treated separately." Transportation on the intracoastal waterways extending from Boston, Mass., to the Rio Grande at Corpus Christi, Texas, is in a somewhat different category than transportation on the Great Lakes. These waterways are designed to meet the interests of small shippers operating motor boats and barges having comparatively shallow draft. A large part of the route runs along the sea coast; some of it utilizes interior channels, while the balance consists of canals or canalized rivers already constructed or in prospect, completely or partially sheltering the traffic from the hazards of the outer ocean. Such waterways, and the traffic moving over them, can be regarded only in part as pertaining to inland waterway proper. While these waterways are included in the present survey, their traffic is included in the traffic totals hereafter discussed only to the extent that it passes through rivers, channels and canals. Coastwise and arm-of-the-sea traffic is excluded.

[12] Report of the Chief of Engineers, U. S. Army, 1937, page 12.
[13] Report of the Chief of Engineers, U. S. Army, 1937, page 26.

TABLE 3

NAVIGABLE LENGTHS AND CONTROLLING DEPTHS OF PRINCIPAL WATERWAYS OF THE UNITED STATES*

Waterways and Systems	Under 4 ft. (Miles)	4 ft. and under 6 ft. (Miles)	6 ft. and under 9 ft. (Miles)	9 ft. and under 12 ft. (Miles)	12 ft. and over (Miles)	Total (Miles)
Atlantic Coast Rivers						
Connecticut River, Conn.	33	------	------	52	------	85
Hudson River, N. Y.	------	------	------	------	141	141
Delaware River, above Philadelphia	------	------	------	------	29	29
Potomac River	------	------	------	------	108	108
Rappahannock River, Va.	------	------	------	66	41	107
York River, Va.	------	------	------	------	41	41
James River, Va.	------	------	------	------	91	91
Neuse River, N. C.	52	23	------	------	34	109
Cape Fear River, N. C.	44	------	67	------	34	145
Waccamaw River, N. C. and S. C.	36	------	------	44	------	80
Savannah River, Ga.	255	------	------	------	------	255
St. Johns River, Fla.	25	------	90	------	83	198
Other Atlantic coast rivers	1,454	815	622	539	444	3,874
Total	1,899	838	779	701	1,046	5,263
Gulf Coast Rivers						
Mississippi River system—Lake Itasca, Minn. to Gulf	500	451	330	913	240	2,434
Illinois River and Waterway	------	------	------	291	49	340
Missouri River	1,895	------	390	------	------	2,285
Ohio River	------	------	------	981	------	981
Monongahela River, Pa., W. Va.	------	------	131	------	------	131
Alleghany River, Pa.	------	------	134	------	------	134
Kentucky River, Ky.	------	------	258	------	------	258
Cumberland River, Tenn., Ky.	156	------	334	------	------	490
Tennessee River, Tenn.	338	260	33	16	------	647
Arkansas River, Ark.	------	322	------	------	------	322
Ouachita and Black Rivers, Ark., La.	67	------	351	------	------	418
Yazoo River, Miss.	------	181	9	------	------	190
Other tributaries	1,680	1,423	727	15	------	3,845
Total, Mississippi River system	4,636	2,637	2,697	2,216	289	12,475
Tombigbee, Warrior and Black Warrior system	674	229	459	------	------	1,362
Withlacoochee River, Fla.	46	32	7	------	4	89
Caloosahatchee River and Lake Okeechobee Drainage area	113	------	24	32	------	169
Bayou Teche, La.	------	------	107	------	------	107
Other Gulf coast rivers	1,901	743	370	145	20	3,179
Total	7,370	3,641	3,664	2,393	313	17,381
Pacific Coast Rivers						
Columbia River system—						
Columbia River, Ore., Wash.	302	125	108	------	105	640
Willamette River, Oreg.	59	------	12	------	13	84
Snake River, Idaho, Oreg, Wash.	218	------	------	------	------	218
Other tributaries	148	4	4	------	------	156
Total, Columbia River system	727	129	124	------	118	1,098
Sacramento and San Joaquin Rivers system—						
Sacramento River, Calif.	105	86	------	46	13	250
San Joaquin River, Calif.	------	------	84	------	41	125
Other tributaries	44	------	------	27	------	71
Total, system	149	86	84	73	54	446
Other Pacific coast rivers	61	65	52	54	20	252
Total	937	280	260	127	192	1,796
Intracoastal Waterways						
Atlantic coast	74	95	657	317	27	1,170
Gulf coast	247	47	34	669	------	997
All other waterways	260	------	------	539	------	799
Grand total, inland waterways	10,787	4,901	5,391	4,746	1,578	27,406

*(Revised to June 30, 1935—Statistical division, Board of Engineers for Rivers and Harbors)

The aggregate navigable length of rivers in the United States now approximates 27,406 miles. This mileage is shown in Table 3, which shows the navigable lengths and control depths of principal waterways of the United States, prepared by the Statistical division, Board of Engineers for Rivers and Harbors, United States Army, revised to June 30, 1935. Of the total mileage, 15,688 miles have a depth of less than 6 ft.; 5,394 miles, depths ranging between 6 and 9 ft.; 4,746 miles, depths ranging from 9 to 12 ft.; and 1,578 miles, depths over 12 ft.

The table also shows a total of 5,263 miles along the Atlantic coast rivers. A total of 12,475 miles embraces the Mississippi river (including the Ohio and the Monongahela rivers) system. Other Gulf Coast rivers aggregate 4,906 miles. The Pacific Coast rivers total 1,796 miles, and the intracoastal waterways total 2,966 miles.

The map exhibit "A" shows the location of the principal waterways of the United States, classified as between (a) waterways improved by the United States and (b) state, foreign and privately-owned waterways. It was prepared from the most recent data released by the office of the Chief of Engineers, U. S. Army in 1936. It relates to the principal improved waterways of the United States, not including sea coast and lake harbors and channels. The channels, both completed and not completed, are subdivided according to depths of less than 6 ft., 6 ft. to less than 9 ft., 9 ft. to less than 12 ft., 12 ft. and over 12 ft.

Reference to the map in connection with Table 3 will show that geographically the inland waterways of the United States fall into about four principal groups, which may be listed as follows:

1. Atlantic coast rivers.
2. Gulf coast rivers—
   (a) Mississippi–Ohio river system;
   (b) Tombigbee, Warrior and Black Warrior system;
   (c) Other Gulf Coast rivers.
3. Pacific Coast rivers.
4. Intracoastal waterways.

Aside from several hundred local projects which have cost large sums of money, the inland waterway development in the United States is being carried on around the principal streams of the Mississippi basin. Those are the Mississippi, Missouri and Ohio rivers, and generally called the Mississippi–Ohio system. The scheme is to follow the completion of improving and deepening the Mississippi–Ohio system and the link to the Great Lakes (Illinois River–Chicago Drainage Canal now complete and the Lake Erie–Ohio River canal project) with the deep water route through the St. Lawrence river to the Atlantic ocean.

Comparative Traffic on Inland Waterways

Table 4 shows the net tons of commercial traffic handled by the inland waterways of the United States for the period 1920 to 1936, inclusive. This information is taken from the report of the Chief of Engineers for the year 1937, Part 2, Table 1, page 4. It represents the waterborne commerce handled on rivers, canals and connecting channels, after eliminating all known duplications of traffic. About 50 per cent of the tonnage (based on 1936 statistics shown in Table 5) is handled on rivers and 50 per cent on canals and connecting channels. An interesting feature of this table is that this character of traffic has increased about 102 per cent during the past 16 years. A part of this increase can be attributed to the collection of more complete tonnage reports in the latter years of the period.

CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
LOWER CALIFORNIA
GULF OF CALIFORNIA
WASH.
OLYMPIA
PORTLAND
ORE.
IDA.
MONT.
N.D.
S.D.
WYO.
COLO.
NEB.
KAN.
OKLA.
TEXAS
N.M.
ARIZ.
UTAH
NEV.
CAL.
SACRAMENTO
SAN FRANCISCO
LOS ANGELES
MINN.
IOWA
MO.
ARK.
LA.
WIS.
ILL.
MICH.
IND.
OHIO
KY.
TENN.
MISS.
ALA.
GA.
FLA.
S.C.
N.C.
VA.
W.VA.
PA.
N.Y.
ME.
VT.
N.H.
MASS.
R.I.
CONN.
N.J.
DEL.
MD.
MISSOURI RIVER
MISSISSIPPI RIVER
OHIO RIVER
ARKANSAS RIVER
RED RIVER
TENNESSEE RIVER
ST. LAWRENCE RIVER
HUDSON RIVER
CHESAPEAKE & OHIO CANAL
ERIE CANAL
DULUTH
BRAINERD
MINNEAPOLIS
ST. PAUL
SIOUX CITY
DAVENPORT
GREEN BAY
CHICAGO
LAKE SUPERIOR
HOUGHTON
SAULT STE. MARIE
LAKE MICHIGAN
LAKE HURON
DETROIT
CLEVELAND
BUFFALO
LAKE ERIE
LAKE ONTARIO
OSWEGO
ALBANY
NEW YORK
PITTSBURGH
BALTIMORE
PHILADELPHIA
MONTREAL
BANGOR
BOSTON
KANSAS CITY
ST. LOUIS
CAIRO
LOUISVILLE
CHARLESTON
WASHINGTON
PORTSMOUTH
NORFOLK
NASHVILLE
CHATTANOOGA
MEMPHIS
LITTLE ROCK
BIRMINGHAM
BEAUFORT
WILMINGTON
CHARLESTON
SAVANNAH
JACKSONVILLE
TAMPA
MIAMI
KEY WEST
MOBILE
NEW ORLEANS
BEAUMONT
HOUSTON
GALVESTON
CORPUS CHRISTI
PT. ISABEL
SCALE - MILES
EXHIBIT "A"
PRINCIPAL WATERWAYS OF THE UNITED STATES
WATERWAYS IMPROVED BY THE UNITED STATES
COMPLETED CHANNELS:
Over 12 feet deep
9 to 12 feet deep
6 to less than 9 feet deep
Less than 6 feet deep
PROJECTED BUT NOT COMPLETED:
Over 12 feet deep
9 to 12 feet deep
6 to less than 9 feet deep
Less than 6 feet deep
STATE, FOREIGN AND PRIVATELY OWNED WATERWAYS
COMPLETED CHANNELS:
Over 12 feet deep
9 to 12 feet deep
6 to less than 9 feet deep
Less than 6 feet deep
PROJECTED BUT NOT COMPLETED:
Over 12 feet deep
9 to 12 feet deep
6 to less than 9 feet deep
BASED ON MAP FROM CHIEF OF ENGINEERS, U.S. ARMY - 1936.

Table 4

Statement of the Waterborne Commerce on Rivers, Canals, and Connecting Channels in the United States, Eliminating All Known Duplications, by Calendar Years

Year	*Short Tons* *Thousands*	*Declared Value* *Thousands*
1920	125,400	$2,814,600
1921	116,300	2,443,500
1922	111,800	3,177,900
1923	153,700	2,960,200
1924	173,200	3,446,035
1925	204,569	3,950,450
1926	217,000	3,680,000
1927	219,000	3,930,000
1928	227,300	3,838,000
1929	245,894	3,871,300
1930	226,760	3,557,000
1931	179,735	2,816,463
1932	151,276	2,589,992
1933	182,965	3,088,615
1934	194,786	3,462,517
1935	225,917	4,286,973
1936	276,263	4,699,343

The text under the following caption is an extract from the Annual Report of the Chief of Engineers, United States Army, 1937, Part 2, pages 2 and 3.

Commerce of Rivers, Canals, and Connecting Channels During the Calendar Year 1936

The statement of commerce (amount of traffic) during the calendar year 1936 on rivers, canals, and connecting channels has been separated into bulk and package (freight) in order to show the relative proportion of low-class and high-class freight transported on our inland waterways. Obvious repetitions of the same commerce have been omitted. Bulk freight is again divided into "Miscellaneous" and "Floated and rafted," the first of which includes commodities handled loose or in cargo lots, consisting principally of coal, coke, ores, lumber, pulpwood, grain, ice, oils, phosphate, and other fertilizer materials, sand, stone, gravel, etc. In some instances fish, oysters, clams, and oyster shells have been included in miscellaneous bulk freight. Floated and rafted traffic, as the name implies, includes logs, piles, poles, and other forest products not transported on barges or other form of vessel. Package freight includes commodities in crates, boxes, bags, or commodities otherwise assembled and, in some cases, lumber, etc., when carried by package freighters.

The traffic on the rivers, canals, and connecting channels is reported under certain heads in order to facilitate the determination of the net traffic. This includes foreign, coastwise, internal, and local and through. Internal traffic is separated into receipts and shipments when there is an interchange between a port and a tributary waterway; inbound and outbound, when there is interchange between two waterways, as for example, between the Monongahela river and the Ohio river; up-bound and down-bound, when the traffic is within the confines of a particular waterway. Sand and gravel, or marine products when taken from the river, are included under local. Through traffic consists of movements over a river, canal, connecting channel, or intracoastal waterway when not loaded or unloaded at a point thereon.

In addition to the federal canals, a number of state and privately owned canals have been included in these statistics.

The total bulk freight on the rivers, canals, and connecting channels, as shown in Table 5, following, amounted to 279,405,134 tons, valued at $2,351,913,057. Of this amount, 262,799,237 tons, with a value of $2,282,405,209, was of a miscellaneous

Table 5*

Commerce of Rivers, Canals, and Connecting Channels of the United States During the Calendar Year 1936

(Quantities expressed in short tons)

	Bulk Freight									
	Miscellaneous		Floated and rafted timber		Total Bulk Freight		Package freight, miscellaneous		Total commerce	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value
Atlantic coast	24,799,815	$323,433,345	612,923	$2.191,635	25,412,738	$325,624,980	3,431,491	$298,249,300	28,844,229	$623,874,280
Gulf coast	10,660,962	94,804,687	794,540	4,006,042	11,455,502	98,810,729	937,410	73,240,794	12,392,912	172,051,523
Pacific coast	4,686,602	30,678,138	12,009,004	47,470,723	16,695,606	78,148,861	1,632,447	158,286,666	18,328,053	236,435,527
Mississippi River and tributaries	83,301,893	597,299,072	687,602	5,323,437	83,989,495	602,622,509	7,726,174	1,040,047,153	91,715,669	1,642,669,662
Interior rivers and other waterways	431,066	1,664,361			431,066	1,664,361	38,662	1,247,525	469,728	2,911,886
Canals and connecting channels:										
Federal	134,479,972	1,139,145,954	2,498,975	10,507,452	136,978,947	1,149,653,406	6,974,585	853,196,316	143,953,532	2,002,849,722
State & private	4,438,927	95,379,652	2,853	8,559	4,441,780	95,388,211	2,365,016	299,372,090	6,806,796	394,760,301
Grand total, unadjusted	262,799,237	2,282,405,209	16,605,897	69,507,848	279,405,134	2,351,913,057	23,105,785	2,723,639,844	302,510,919	5,075,552,901
Adjusted total, eliminating all known duplications									276,263,926	4,699,343,012

*This table appears as Table 3, page 5 of the Annual Report of the Chief of Engineers, United States Army, 1937, Part 2.

character, and 16,605,897 tons, valued at $69,507,848, consisted of floated and rafted timber. The average value of the miscellaneous bulk freight carried by vessels was about $9 per ton, and that of the floated and rafted timber about $4.

The package freight amounted to 23,105,785 tons, valued at $2,723,639,844, having an average value of about $118 per ton.

The gross total commerce on the rivers, canals, and connecting channels was 302,510,919 tons, valued at $3,075,552,901, which included 4,201,313 tons of foreign imports, valued at $145,125,835, and 3,566,498 tons of exports, valued at $196,178,483. After eliminating all known duplications of traffic between different rivers, canals, and connecting channels, the adjusted total amounted to 276,263,926 tons, valued at $4,699,343,012.

The gross traffic on the Mississippi river and its tributaries, including the Ohio River system, amounted to 91,715,669 tons, valued at $1,642,669,662. After eliminating all known duplications, the net total tonnage was 73,902,220 tons, valued at $1,387,534,784.

The gross traffic on the Ohio river and its tributaries amounted to 59,451,154 tons, valued at $419,425,284. After eliminating all known duplications, the net total tonnage was 43,715,740 tons, and the value, $286,358,155.

The net traffic of the Mississippi river from Minneapolis, Minn., to the Passes amounted to 27,625,485 tons, valued at $1,108,549,641. Since 1935, statistics have been compiled showing the total net traffic on the Mississippi river proper from Minneapolis to the Passes at the mouth, and the figures given include the traffic of the port of New Orleans, La., formerly excluded.

The total ton-mileage on the inland waterways of the United States, exclusive of the Great Lakes, was 15,322,016,818. The total ton-mileage on the Great Lakes was 77,263,645,000, which together with that on the rivers, canals, and connecting channels made a total ton-mileage of 92,650,735,772.

Transportation in the United States Measured by Ton-Miles of Traffic Handled

The ton-mile is perhaps the best single unit of measure that may be used in comparing the volume of traffic handled by various agencies. The Bureau of Railway Economics has prepared a statement showing commercial freight traffic for the year 1936, which gives the ton-miles and the percent of total of the various agencies of transportation. This information follows, in Table 6, together with the source and other supporting data. In addition to the figures for 1936, similar data for 1928 have been added, the source of which is from the "Study of Inland Waterway Situation," by Samuel S. Wyer, March, 1931, page 17. The table shows the *revenue ton-miles* handled by the railroads and the *potential ton-miles* additional they would handle if it were not for the other transportation agencies.

Percentages based upon the totals, exclusive of the Great Lakes tonnage, indicate that in 1936 steam railways handled 79.7 per cent, as compared with 90 per cent in 1928. The pipe lines handled 7.2 per cent in 1936, as compared with 5.9 per cent in 1928. The waterways handled 3.5 per cent in 1936, as compared with 1.9 per cent in 1938. The electric railways handled approximately 0.2 per cent in both 1936 and 1928. The traffic handled by the airways in 1936 is based upon domestic express ton-miles. It constitutes less than 0.01 per cent. Similar information not available for 1938. Intercity trucks handled 9.4 per cent in 1936, compared with 2 per cent in 1928.

The tonnage on the Great Lakes decreased from ninety billion ton-miles in 1928 to seventy-seven billion, one hundred and eighty-two million ton-miles in 1936. The total of all traffic decreased from six hundred and twenty billion ton-miles in 1928 to five hundred and five billion, four hundred and seventy-five million ton-miles in 1936. This decrease in the total of all traffic handled, aggregating 18.5 per cent, may be accounted for by the relative difference in business conditions in those two years.

Table 6

Commercial Freight Traffic in the United States

	1928		1936	
	Ton-Miles	*Per Cent of total*	*Ton-Miles*	*Per Cent of total*
	(In thousands)			
1. Steam railways	477,200,000	90.0	341,181,600	79.7
2. Pipe lines	31,200,000	5.9	30,709,700	7.2
3. Waterways	10,000,000	1.9	15,387,100	3.5
4. Electric railways	1,300,000	0.2	704,500	0.2
5. Airways	--------	--	1,900	--
6. Intercity trucks	10,300,000	2.0	40,227,700	9.4
Total	530,000 000	100.0	428,293,800	100.0
7. Great Lakes	90,000,000	----	77,181,600	----
Grand Total	620,000,000	----	505,475,400	----

Source:

1. 1936 Annual report "Statistics of Railways in the United States"—Interstate Commerce Commission.
2. Ton-miles of oil (crude and refined) are estimated, based on traffic originated by pipe-line carriers reporting to the Interstate Commerce Commission. Figures originally reported in barrels, were here converted to tons of 2,000 lb. on the basis of 42 gal. per. bbl., 7.4 lb. per gal.; and an average haul of 245 miles. The average haul used is in accord with the following statement taken from Senate Document No. 152, page 262: "The average length of haul (pipe line) is not accurately known, but an estimate of 245 miles (1932) has been furnished by an expert familiar with the industry."
3. 1937 Annual Report of the Chief of Engineers. U. S. Army—Part 2. Figures for "Canals and Connecting Channels" exclude Great Lakes traffic.
4. Ton-miles estimated by applying to the total freight revenues of all electric railways reporting to the Interstate Commerce Commission an average revenue per ton-mile of three cents.
5. From "Air Commerce Bulletin," U. S. Department of Commerce, June 15, 1937, issue. Figures shown cover only express ton-miles of domestic service. Figures do not include ton-miles of mail (domestic) in 1936, which amounted to 5,741,436.
6. *Ton-Miles of Intercity Trucks Estimated*—The latest available official figures of ton-miles of intercity trucks are those of the federal co-ordinator of transportation in his report on "Regulation of Transportation Agencies." The ton-miles for intercity trucks shown therein for the year 1932 amounted to .. 29,976,800,000

   Estimates for the year 1936.—Utilizing the same factors as those used by Mr. Eastman in arriving at his estimate for 1932, namely, 638,350 trucks and combinations, 17,720 miles per truck per year, and 2.65 tons of average load, and assuming that trucks and tractors in intercity service increased from 1932 to 1936 at the same ratio as did the total registrations of trucks and tractors (including both intercity and local units), the ton-miles of intercity trucks for year 1936 would be 37,290,000,000

   Using Mr. Eastman's above factors of 17,720 miles per truck per year and 2.65 tons of average load. and applying them to the increase in registrations, 1936 over 1932, of trucks and tractors, including trailers and semi-trailers, the estimate of ton-miles in intercity trucks would be 40,227,000,000

Using the coordinator's estimate for year 1932 and applying to it the same per cent of increase for steam railways, 1936 over 1932, of 45 per cent, the ton-miles of intercity trucks in 1936 would be 43,000,000,000

"Hale's Chart" shows ton-miles of trucks in 1936 to be about 24,000,000,000

7. 1937 Annual Report of the Chief of Engineers, U. S. Army—Part 2. Figures exclude traffic between foreign ports on the Great Lakes.

Table 7 shows a comparison of the waterborne traffic in the United States divided on the various divisions of rivers and canals for the years 1928 and 1936. From this, it will be seen that, exclusive of the Great Lakes, the percentage of traffic on the Mississippi–Ohio River system increased from 60.65 per cent in 1928 to 65.28 per cent in 1936. The total inland waterway tonnage increased from 9,336 million ton-miles in 1928 to 15,387 million ton-miles in 1936, or 65 per cent. The traffic on the Great Lakes decreased from 87,178 million ton-miles in 1928 to 77,264 million ton-miles in 1936, or 11.4 per cent.

Table 7

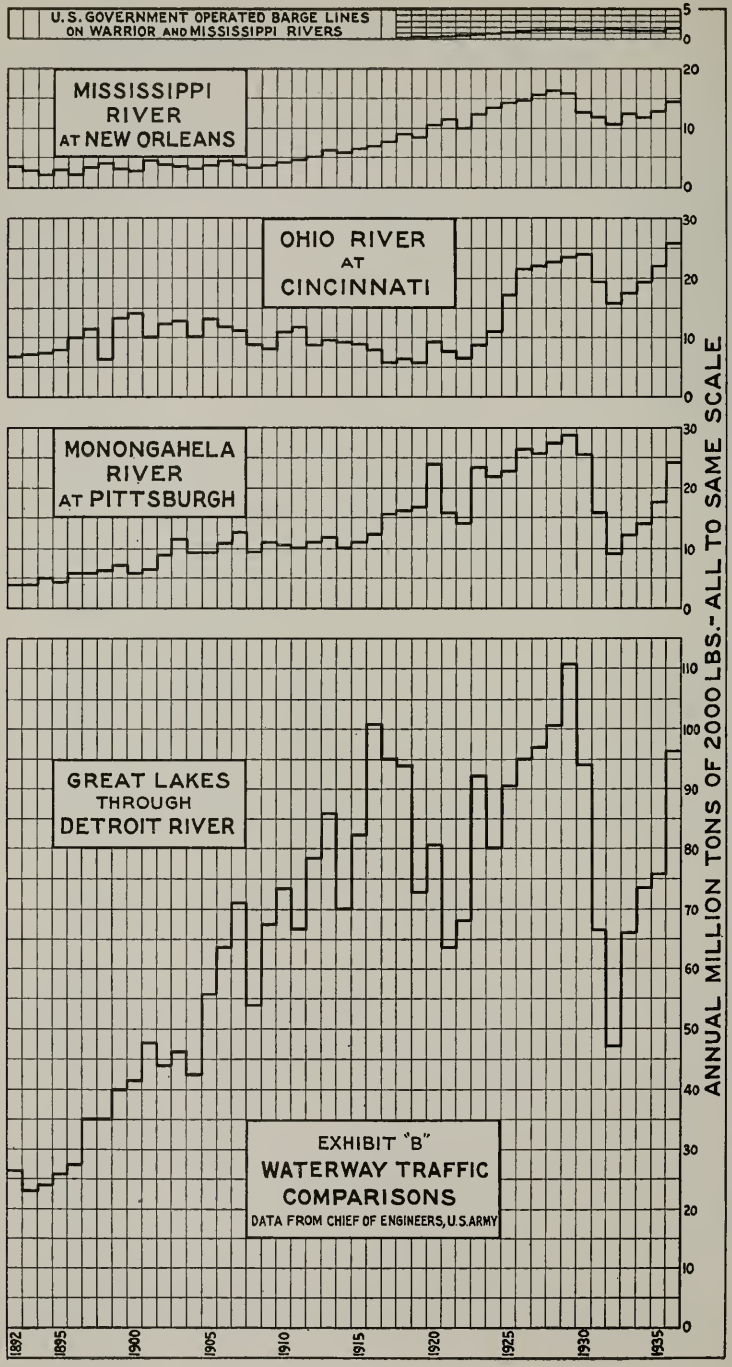
Waterborne Traffic of the United States

	1928 (a)		*1936 (b)*	
	Ton-Miles	*Per Cent*	*Ton-Miles*	*Per Cent*
	(In thousands)			
Mississippi–Ohio system	5,662,743	60.65	10,044,061	65.28
Atlantic Coast rivers	1,419,242	15.20	1,645,759	10.70
Gulf Coast rivers	436,605	4.68	516,054	3.35
Pacific Coast rivers	733,846	7.86	957,511	6.22
Other waterways	13,739	0.15	9,593	0.06
Canals and channels	1,069,977	11.46	2,214,113	14.39
Inland waterways	9,336,152	100.00	15,387,091	100.00
Great Lakes System	87,178,118		77,263,645	
Total waterborne	96,514,270		92,650,736	

Sources: Annual Report of the Chief of Engineers, U. S. Army, (a) 1929, Part 2, page 29; (b) 1937, Part 2, page 35.

Exhibit "B" shows a chart of waterborne commerce of the United States in millions of tons, on the Great Lakes through the Detroit river, the Monongahela river at Pittsburgh, the Ohio river at Cincinnati, and the Mississippi river at New Orleans for the period 1892 to 1936 inclusive, and, also, the tonnage handled by the United States government-operated barge lines on the Warrior and Mississippi rivers from 1918 to 1936, inclusive, based on data from Chief of Engineers, United States Army.

It is not the intention of this committee to deal with transportation on the Great Lakes. While the Great Lakes—Michigan, Superior, Huron, Erie and Ontario—are generally considered a part of our inland waterways, in reality they are inland seas not comparable in any respect to the rivers and canals constituting our other inland waterways. The Great Lakes were entirely made by nature, and the expenses incident to port or harbor developments are quite similar to port and harbor developments at tidewater. The water levels are regulated by nature, varying about three feet, as compared to a much greater spread on the Ohio and other rivers. Nature also brought about extensive deposits of ore beds at the upper end of the Great Lakes, and large deposits


U.S. GOVERNMENT OPERATED BARGE LINES ON WARRIOR AND MISSISSIPPI RIVERS
MISSISSIPPI RIVER AT NEW ORLEANS
OHIO RIVER AT CINCINNATI
MONONGAHELA RIVER AT PITTSBURGH
GREAT LAKES THROUGH DETROIT RIVER
EXHIBIT "B"
WATERWAY TRAFFIC COMPARISONS
DATA FROM CHIEF OF ENGINEERS, U.S. ARMY
ANNUAL MILLION TONS OF 2000 LBS. - ALL TO SAME SCALE
0
10
20
30
40
50
60
70
80
90
100
110
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935

of coal at the lower end, the combination of which, together with large industrial developments at the lower end, has brought about an enormous volume of tonnage for transport on the Lakes.

The chart shows a total of about 26,000,000 tons transported on the Great Lakes through Detroit River in 1892, and in excess of 100,000,000 tons were transported in 1916 and 110,000,000 in 1929, the figure for 1936 being 96,777,000 tons. The bulk of this traffic, of course, is coal and ore, the World War affecting the volume of tonnage in 1916 and industrial expansion in 1928. The total gross domestic United States commerce on the Great Lakes, after eliminating all known duplications, amounted to 122,788,000 tons in 1936.

A total of about 4,000,000 tons was transported on the Monongahela River in 1892, 28,000,000 tons in 1929, and 24,652,000 in 1936.

Records of tonnage carried on the Ohio River at Cincinnati show that 7,000,000 tons were handled in 1892, 24,000,000 tons in 1929, and 25,693,000 tons in 1936.

At New Orleans, the Mississippi carried 3,500,000 tons in 1892, 16,000,000 tons in 1929, and 14,332,000 tons in 1936.

This chart also records the traffic handled by the United States Government-operated barge lines on the Warrior and Mississippi rivers from 1918 to 1936. In 1929, 1,575,000 tons were carried. The maximum on record was in 1936, when 2,110,000 tons were transported by this government-operated agency. These operations will be the subject of a future report of this committee.

For members and others desiring to make a more comprehensive study, a bibliography, comprising the various articles reviewed to date, is appended as Exhibit "C", for ready reference.

It is the opinion of your committee that the subject of this assignment is of vital interest to the railways, and it is recommended that the report be received as information.

Exhibit "C"

A Bibliography of Articles Relating to the "Effect of Inland Waterway Transportation on the Economics of Railway Operation"

Article	Author or Source	Publication and Date
The Relation of the Ohio River and Its Tributaries to Transportation in the United States	C. W. Kutz	Transactions of the A. S. C. E.—Vol. 89, 1926—p. 1106
The Relation of the Ohio-Mississippi Waterways to Production and Industrial Development	H. B. Luther	Transactions of the A. S. C. E.—Vol. 89, 1926—p. 1123
Comparison of Rail and River Transportation Costs in Relation to the Ohio River and Its Tributaries	Frank H. Alfred	Transactions of the A. S. C. E.—Vol. 89, 1926—p. 1127
Water Transportation Versus Rail Transportation: A Symposium	(See two articles following)	Proceedings, A. S. C. E, Sept., 1937—p. 1229
The Value of Water Transportation	Rufus W. Putnam	Proceedings, A. S. C. E., Sept., 1937—p. 1230
The High Cost of Inland Water Transportation	S. L. Wonson	Proceedings, A. S. C. E., Sept., 1937—p. 1246
Economics of the Ohio River Improvement	C. L. Hall	Proceedings, A. S. C. E., Oct., 1937—p. 1485
Water Transportation Versus Rail Transportation	George Hartley	Proceedings, A. S. C. E., Oct., 1937—p. 1666
Water Transportation Versus Rail Transportation: A Symposium	W. D. Faucette and J. E. Willoughby	Proceedings, A. S. C. E., Dec., 1937—p. 1989
Economics of the Ohio River Improvement	Eugene L. Grant	Proceedings, A. S. C. E., Dec., 1937—p. 2010
Water Transportation Versus Rail Transportation: A Symposium	C. D. Bordelon	Proceedings, A. S. C. E., Jany., 1938—p. 189

Exhibit "C"—Continued

A Bibliography of Articles Relating to the "Effect of Inland Waterway Transportation on the Economics of Railway Operation"

Article	Author or Source	Publication and Date
Water Transportation Versus Rail Transportation: A Symposium	J. E. Goodrich	Proceedings, A. S. C. E., Feby., 1938—p. 354
Economics of the Ohio River Improvement	Fred Lavis, O. Slack Barrett, and Edmund L. Daley and Forrest E. Byrns	Proceedings, A. S. C. E., Feby., 1938—p. 374
Water Transportation Versus Rail Transportation: A Symposium	H. R. Faison	Proceedings, A. S. C. E., March 1938—p. 566
Economics of the Ohio River Improvement	W. E. R. Covell	Proceedings, A. S. C. E., May, 1938—p. 957
Water Transportation Versus Rail Transportation: A Symposium	Rufus W. Putnam and S. L. Wonson	Proceedings, A. S. C. E., June, 1938—p. 1187
Economics of the Ohio River Improvement	C. L. Hall	Proceedings, A. S. C. E., June, 1938—p. 1204
Report of the Mississippi Valley Committee of the Public Works Administration	Morris L. Cooke, chairman	Oct. 1, 1934
The Interterritorial Freight Rate Problem of the United States	Tennessee Valley Authority—Arthur E. Morgan, chairman of the Board	75th Congress, 1st Session—House Document No. 264
Annual Report of the Inland Waterways Corporation	T. Q. Ashburn, major general, U. S. Army, chairman of the board, president, Inland Waterways Corporation	1929-1937
Report of the Chief of Engineers, U. S. Army, 1937—Vols. I and II	E. M. Markham, major general, chief of engineers	75th Congress, 2nd Session—House Document No. 375
Report on the Lake Erie and Ohio River Canal	Coverdale and Colpitts	Sept. 27, 1932
The Lake Erie and Ohio River Canal—Beaver-Astabula Route—A synopsis with complete report on its economic aspects	Upper Valley Association, Pittsburgh, Pa.	
Proposed Canal Between the Ohio River and Lake Erie via the Beaver, Mahoning and Grand Rivers—Brief of Upper Ohio Valley Ass'n	U. S. War Department—Board of Engineers for Rivers and Harbors	March 30, 1936
A Study of Inland Water Situation	Samuel S. Wyer	March, 1931
Report Upon Survey for Canal Connecting Lake Erie with Ohio River	W. E. R. Covell, Lt. Col. Corps of Engineers, U. S. Engineer Office, Pittsburgh, Pa.	February 24, 1937
An Economic Survey of Inland Waterway Transportation in the United States	Bureau of Railway Economics, Washington (Special Series No. 56)	1930
St. Lawrence Navigation and Power Project	Harold G. Moulton and Associates (Brookings Institution)	
The American Transportation Problem	Harold G. Moulton and Associates (Brookings Institution)	1933
Study of St. Lawrence Waterway Project	Samuel S. Wyer	August, 1934
Waterways	Editorial	Railway Engineering and Maintenance, August, 1938.
Statistics of Waterways, United States	Bureau of Economics, A. A. R.	December, 1934
The Gulf Intracoastal Waterway	Corps of Engineers, U. S. Army, Gulf of Mexico Div.	April 15, 1938
The Intracoastal Waterway, Boston, Mass., to the Rio Grande	War Department, Chief of Engineers, River and Harbor Section	October, 1937
Navigation on the Ohio River	Corps of Engineers, U. S. Army (office of Division Engineer, Cincinnati, O.)	1938
Improvement of the Missouri River	Corps of Engineers, U. S. Army	January, 1938
The Upper Mississippi River Navigation Improvement	U. S. Division Engineer, U. M. V. D., St. Louis, Mo.	February, 1938
What is Wrong With The Railways?	H. D. Angus, Relieving Agent, C. N. Rys.	Proceedings, Canadian Railway Club, September, 1938

Appendix F

(7) EFFECT OF HIGH SPEED ON RAILWAY OPERATING EXPENSES

M. F. Mannion, Chairman, Subcommittee; E. G. Allen, B. T. Anderson, V. T. Boughton, C. W. Breed, Olive W. Dennis, G. W. Hand, G. D. Hughey, J. F. Pringle, C. P. Richmond, H. F. Schryver, B. J. Schwendt, L. K. Sillcox, H. M. Tremaine.

Railway Operating Expenses are composed of the following General Accounts:—

Maintenance of Way
Maintenance of Equipment
Traffic
Transportation Rail Line
Miscellaneous Operations
General

In previous years Committee 21 reported that traffic, miscellaneous operations and general expenses are affected very little, if at all, by traffic. It is therefore a reasonable and logical assumption that these expenses are not affected by increased speeds and can therefore be disregarded in any study of the effect of high speed on operating expenses. This leaves the three major general accounts, maintenance of way, maintenance of equipment and transportation rail line expenses to be studied.

Maintenance of Way Expenses

Last year Subcommittee 4 of Committee 16 reported as follows:—

"By the application of the well-known laws of dynamics, it is obvious that high-speed trains of equal weight with those traveling at slower speeds are more destructive of track and roadbed. However, many of the new high-speed passenger trains today are considerably lighter in weight than other and older trains. Also, the power units hauling these trains are either without reciprocating parts or they are in such nice adjustment to the work they are doing that damaging effects can not be traced to their operation. Again trains of this class are in all cases operated on the same tracks with other trains of lower speeds, and usually with all classes of freight trains. It is therefore difficult, if not impossible, to determine how much of disturbances of the track-line-surface, gage, etc., are attributable to the high-speed trains. Further and greater diversity of experience will be required for definite determination of these effects.

"Reference is made to the report of Committee 22 on 'The Effect of High Speeds on the Labor Cost of Track Maintenance', which will be found in Appendix F of that committee's report, page 375 of Volume 38 of the Proceedings."

Up to the present time no additional information or data have been obtained on this group of expenses.

Maintenance of Equipment Expenses

What has been said regarding the lack of experience and data, and the difficulty of definitely determining the effect of high speed on maintenance of way expenses, is equally true of maintenance of equipment expenses. It is obvious that the use of brakes due to the greater amount of energy that must be dissipated by them when stopping or retarding high speed trains will be more destructive to wheels than in the case of slower trains of equal weight. However, the fact is that in practically all cases the weight of high speed trains is less than the slower trains. Again speed is only one of the many causes of wear and tear, and its damaging effect on equipment is very difficult to determine. Again, the actual maintenance cost of the new light weight equipment is not known as

it has not been in service throughout a complete life cycle and the actual cost data are not available.

High speed operation may increase or decrease the number of units of equipment necessary to handle the traffic of a particular railroad or subdivision, thereby either increasing or decreasing the total equipment expenses. If high speed operation results in increased mileage per month for the equipment, the number of units required will be less, provided the power of the units is sufficient to handle the same train load at the higher speed. If the power is not sufficient the train load will have to be reduced, requiring the running of additional trains, or additional power units must be added, which will increase maintenance of equipment expenses. In the analysis of transportation expenses the effect of this feature on equipment maintenance can be determined.

Before the effect of high speed on standard equipment wear and tear, and reliable equipment maintenance cost for new light weight equipment can be accurately estimated, larger and greater diversity of experience will be necessary.

Transportation Rail Line Expenses

An analysis of the effect of high speed on transportation cost should develop the increase or decrease in this expense due to higher speeds with present standard equipment and also a comparison of total transportation cost per unit of service, such as the gross ton-mile and passenger train-mile, between present standard equipment and new light weight equipment. This comparison cannot be based on the cost of a high speed train as against the cost of a slower train but must also develop the effect of the high speed train on all other trains. This requires an analysis of the train sheets to determine the extent to which the time of all trains was affected by the inauguration of high speed service. The comparison must also include an analysis of the power unit characteristics in order to develop the hauling capacities of the power units at various speeds.

The committee has obtained copies of the train sheets on one operating division for a 15-day period prior to and after the operation of a high speed train but as yet have not completed its study of them. The committee has also partially completed a tabulation showing the tonnage that can be handled by different classes of locomotives at different speeds.

It is recommended that this progress report be accepted as information.

Appendix G

(8) EFFECT OF RAIL OILING ON TRAIN OPERATION

J. A. Parant, Chairman, Subcommittee; Richard Brooke, E. B. Crane, R. P. Forsberg, C. H. R. Howe, E. A. Humphreys, F. H. McGuigan, Jr., L. G. Morphy, H. R. Peterson, B. H. Prater, L. S. Rose, H. M. Tremaine, R. E. Van Atta.

This is a new assignment to this committee.

The use of oil on the track structure of the main traffic lines of American railroads began about 27 or 28 years ago. It was introduced and used in the beginning to combat the destructive effects of brine drippings on the track joints—angle bars, bolts, nuts, and nut locks. This protective use was extended to include the spikes, tie plates, rail anchors, tie rods and at least the movable parts of switches and frogs; and on some railroads oil was used to protect the ties under tie plates; and then it was sometimes applied to rails on the base, web and under the angle bars. During the first 12 or 15 years the applica-

tion of oil to track fastenings was generally made by hand with brushes, although a few railroads made the applications with machines.

Oil has been used on the track structure of railroads also in the form of lubricant, applied either on the side of the rail heads or the faces of the wheel flanges to eliminate or reduce the abrasive wear on both the heads of rails in curves and the wheel flanges of equipment. This method was initiated experimentally some 15 years ago, and has been carried on systematically by a considerable number of roads for 12 years or longer. Since these early applications demonstrated the effectiveness of this means of reducing the wear of rails and flanges, an increasing number of railroads have adopted rail-flange lubrication on curves. The lubricants have been applied by hand (watchmen and track laborers) or by automatic mechanical devices.

Committee 5—Track, has studied and contributed valuable reports on (1) the application of oil to track fittings for protection against corrosion, and (2) the reduction of rail and wheel wear by lubrication of the faces of the rail head and the wheel flanges. These are well covered and include the kinds of oil, frequency and methods of application, types of mechanical lubricators, selection of sections of track to be protected, costs, extent of the practice, results obtained, etc. Reference is made to these reports, as follows:

(1) Proceedings Vol. 24 (1923); Appendix I, pages 480–502.
(2) Proceedings Vol. 29 (1928); Appendix F, page 602
Proceedings Vol. 30 (1929); Appendix F, pages 924–928
Proceedings Vol. 31 (1930); Appendix F, pages 592–597
Proceedings Vol. 32 (1931); Appendix I, pages 160–163
Also (3) Lubrication of rail on curves:
Proceedings Vol. 39 (1938); Appendix G, pages 419–421

In addition to a reduction in the maintenance of both track and equipment it is believed by some that lubrication of rail-wheel flanges results also in a distinct reduction in tractive resistance, through a decrease in one of its factors—curve resistance. The officers of a northeastern railroad are thoroughly convinced that the economies in train operation realized from this practice are greater than the savings in maintenance brought about by the reduction in wear of rail and flanges. An important railway in the northwest after ten years' experience with its initial installation of oilers, in territory of heavy ore traffic, which have been largely augmented by subsequent additions, failed to offer any comparison of the relative advantages of lubrication to maintenance and to operation, but contributed a very positive opinion to the effect that substantial operating advantages accrue from the practice.

The conclusions of logic, that since the wear on rail and flange is the result of abrasive action requiring a definite effective effort, any reduction in abrasion or wear must result from a reduction in the effective force, are reasonable. However a clear demonstration of the fact, and a determination of the amount of reduction of the resistance on curves of various degrees and angles are not easy. Observations of these difficulties have been made by engineers of eastern and western railways, who have been observers on dynamometer cars in trains operated through lubricated curves, in connection with a consideration of the possibilities of the dynamometer car as a means of determining the effects of rail-flange lubrication on tractive resistance. Further examination of the possibilities of obtaining satisfactory data reflecting on this problem by the application of this method will be made. Contribution of results of such tests and measurements is solicited from all those who have made such runs and have or can obtain and furnish the data resulting therefrom.

The making of special laboratory tests as a determinant of this problem is the only alternate method of attack that has been suggested. Initial steps for having such tests made, have been taken. It may not be too much to hope that, by another year, data on which definite conclusions may be based will be available.

It is recommended that this introductory presentation be received as a report of progress.

Appendix H

(9) COMPILE OPERATING DATA ESSENTIAL TO ESTABLISH UNITS FOR MAKING LINE AND GRADE REVISIONS TO MEET OPERATING REQUIREMENTS

J. M. Farrin, Chairman, Subcommittee; E. Y. Allen, J. C. Bradley, C. W. Breed, S. B. Clement, H. H. Edgerton, J. L. Haugh, W. B. Irwin, Fred Lavis, R. S. Marshall, F. N. Nye, H. W. Snyder, H. M. Tremaine, J. S. Worley.

The fundamental requirement to justify either line or grade revisions is that when completed the resulting operation will show a profit sufficient to pay a return on the total cost of the improvement. Generally speaking, this return should total 15 percent, of which 5 percent is to cover interest charges, and 10 percent is to take care of certainties and fluctuations of traffic. In lieu of a profit there may be special cases in which competition will force an improvement irrespective of its cost, but in either event the total cost of conducting traffic before and after changes should be determined for the information of all concerned.

There are three ways in which operation can be bettered, namely:

(a) Line and grade revision
(b) Substitution of heavier and more modern power
(c) More intensive supervision

Generally speaking, line and grade revisions affect both tonnage of trains and coal consumed while the substitution of heavier power usually affects only tonnage of trains. Operating data to compare costs of (a) and (b) are similar and as (c), more intensive supervision, does not involve such data, it will not be discussed further.

Development of Present Costs

In order to develop present costs it is necessary that the following traffic data for a period of at least one year, in which traffic is normal, be obtained for the district being considered:

1. Gross ton-miles of freight traffic, including locomotives, in each direction.
2. Gross ton-miles of passenger traffic, including locomotives, in each direction.
3. Number of each class of freight trains in each direction divided to show:
   (a) Number of fast freight trains each way.
   (b) Number of slow freight trains each way.
   (c) Number of local freight trains each way.
4. Number of passenger trains each way.
5. Number of freight-train miles.
6. Number of passenger-train miles.
7. Number of freight-train hours.
8. Number of freight locomotives of each type and size.
9. Number of passenger locomotives of each type and size.
10. Number of locomotive miles.
11. Number of helper locomotive miles.
12. Number of gross tons per train-hour in freight service.

13. Cost of coal consumed in freight service.
14. Cost of coal consumed in passenger service.
15. Cost of water consumed in freight service.
16. Cost of water consumed in passenger service. (Water to be figured on basis of seven pounds of water per pound of coal)
17. Cost of oil and other supplies, freight service.
18. Cost of oil and other supplies, passenger service.
19. Cost of locomotive repairs per locomotive mile.
20. Wages of enginemen, freight service, per hour, including overtime.
21. Wages of trainmen, freight service, per hour, including overtime.
22. Maintenance of way and structures expense for the district.

With the selected items of expense, the approximate cost of the present operation can be figured and arranged in tabular form after which the same information should be estimated for the proposed improvements. Attention is called here to the fact that in case the proposed improvement is such that longer trains can be hauled or larger and heavier motive power substituted, it will be necessary to consider the length and location of sidings, the strengthening of bridges, signal changes, enginehouse enlargements and other special work and add the cost of changes required to get a total cost of the improvement upon which to determine whether or not it is justified. Also, heavier trains generally mean more road time which may increase overtime.

With the information on present costs, a comparison with the expense of operation after the improvements have been completed is arrived at as shown in Statement A.

Expense items making up Statement A may be arrived at as follows:

1. Total Cost

This item will be zero under the present operation and must be estimated for the proposed operation.

2. Interest

This item is generally taken at five percent of the total out-of-pocket cost of the improvement, and should include the cost of new power purchased to make the improvement effective, but should not include the transfer of power from other districts. There will be no charge for this item under present operation.

3. Replacement

This item will be zero under the present operation. Under the proposed operation charge as follows:

Rail and Fastenings: Charge only for that portion in excess of that used in the present operation on the following basis:

Cost in place less salvage value

90-lb. rail life 215,000,000 tons
100-lb. rail life 255,000,000 tons
112-lb. rail life 320,000,000 tons
131-lb. rail life 400,000,000 tons

Decrease the tonnage life of rail on curves ten percent for each degree of curvature for curves up to six degrees and five percent from six degrees to ten degrees. Where curves are lubricated, the above percentages should be reduced 5 percent and 2½ percent respectively.

Bridging steel: Life of 50 years.
Wood creosote: Life of 25 years.
Enginehouse additions: Life of 50 years.
Other buildings: Life of 50 years.
Signals: Life of 30 years.

4. Transportation Costs

Items under this head represent a charge to both present and proposed operations but in different amounts.

Wages for items (a), (b), (c) and (d) are governed by agreements with the men pertaining to each particular railroad and to districts on the same railroad, and vary with mileage, time, and class of engine. Costs for these items having been developed for present operations their costs for proposed operations should be estimated, taking overtime into consideration.

Engine Terminal Expense: For present and proposed operations this is the cost of handling the power at terminals, which may not be the same, and if there is a difference, charges for each must be determined and added. These charges should be arrived at on a total charge basis rather than a charge per engine as this account takes in so much supervision and general expense that variation of a few engines may not affect its total appreciably.

Fuel: This item is sometimes hard to allocate, especially for short districts, but as it generally is an important item of expense, its present cost must be determined fairly accurately. If the proposed improvement does not involve changes affecting grade, the unit cost of present operation per 1,000 gross ton-miles can be used. If the grade is affected the pounds of coal can be determined for differences of grades on the basis of 3.3 lb. of coal per 1,000 tons per foot raised. Similarly coal saved in curve reduction can be readily obtained.

Water: Water consumed is in direct ratio to coal used on the basis that one pound of coal evaporates seven pounds of water. Charge the price of water at 10 cents per 1,000 gal. to both present and proposed operations.

Lubricants: This item is small and it is sufficiently accurate to charge both present and proposed operations per locomotive mile on the basis of present costs.

Other Supplies: This item is small. Charge both present and future operations per locomotive mile on the basis of present costs.

5. Maintenance of Equipment

Freight and Passenger Locomotives: This item varies greatly with the class of locomotives and their speed. However, it is sufficiently accurate to use the system cost per locomotive mile for each class of locomotive and multiply this figure by miles run by each class of locomotive over the district being considered and make proper charges to both present and proposed operations. Car maintenance is indeterminate and ordinarily need not be considered.

6. Maintenance of Way and Structures

Way: This item varies with the location, amount and character of traffic and standard of maintenance, which makes it necessary to develop actual costs for each location which costs may then be applied on a mileage basis to both present and proposed operation, giving consideration to new roadbed and drainage. Improvements involving a change in the size of rail will affect maintenance as follows:

Assume 131-lb. rail equals 1.00, then
112-lb. rail will cost 1.18 times
110-lb. rail will cost 1.37 times
90-lb. rail will cost 1.54 times

Structures: Steel Bridges: This item will be zero for the present operation and 75 cents per additional lineal foot per year for lengths up to 200 ft. For longer lengths make a special investigation.

Creosoted Wooden Bridges: This item will be zero for the present operation and average 30 cents per additional foot per year for the proposed operation.

Buildings: This item will be zero for the present operation and two percent per year for increase in size or number of buildings for the proposed operation.

Signals: This item will be zero for the present operation and $150 per year per mile for single track and $200 per year per mile for double track, and subject to special investigation for the proposed improvement.

7. Taxes

Where these are a factor they should be considered.

It is recommended that this report be received as information.

STATEMENT "A"

ANNUAL COST OF PRESENT OPERATIONS COMPARED WITH ESTIMATED COST AFTER IMPROVEMENTS ARE MADE

Item	*Present*	*Proposed*
1. Total cost of improvements complete including changes in sidings, terminals, signals, additional power, etc.	0	--------
Annual Cost		
2. Interest on cost, 5 per cent	0	--------
3. Replacement		
(a) Rail and fastenings including sidings	0	--------
(b) Bridging, steel	0	--------
Creosoted trestles	0	--------
(c) Enginehouse additions	0	--------
(d) Other buildings	0	--------
(e) Signals	0	--------
4. Transportation Costs		
(a) Wages, freight enginemen	--	--------
(b) Wages, passenger enginemen	--	--------
(c) Wages, freight trainmen	--	--------
(d) Wages, passenger trainmen	--	--------
(e) Enginehouse expense	--	--------
Freight	--	--------
Passenger	--	--------
(f) Fuel, freight	--	--------
Passenger	--	--------
(g) Water, freight	--	--------
Passenger	--	--------
(h) Lubricants, freight	--	--------
Passenger	--	--------
(i) Other supplies, freight	--	--------
Passenger	--	--------
5. Maintenance of Equipment		
(a) Freight locomotives	--	--------
(b) Passenger locomotives	--	--------
6. Maintenance of Way and Structures		
(a) Way	0	--------
(b) Structures: Steel bridges	0	--------
Creosoted trestles	0	--------
(c) Buildings	0	--------
(d) Signals	0	--------
7. Taxes	0	--------
Total Annual Cost	--	--------

Appendix I

(11) SPIRALS REQUIRED FOR HIGH-SPEED OPERATION

H. M. Shepard, Chairman, Subcommittee; E. G. Allen, S. E. Armstrong, J. C. Bradley, H. C. Crowell, Olive W. Dennis, R. P. Forsberg, E. A. Humphreys, L. G. Morphy, B. H. Prater, E. H. Roth, F. A. Russell, O. E. Selby.

Historical Data

The necessity for the use of an easement curve was recognized shortly after the Civil War. Both Rankine and Wellington made reference to its use, and in 1880 the Holbrook spiral was made public. In 1882 Searles published the first edition of the Railroad Spiral. Since the earliest use of an easement curve, a close approximation to the cubic parabola has been followed, but there have been a multitude of methods of computing and staking the curve.

The Railroad Gazette of May 24, 1895, carried an article by Walter L. Webb, based on 18 replies to a questionnaire sent to all the leading railroads. Roughly, 75 percent reported the use of an easement curve, and others made use of them in special cases. The notable exceptions were two large eastern railroads. These companies used no easement, but on main-line curves in excess of 4-deg., they introduced a 2-deg. compounding curve at each end. The replies from the other roads disclosed a variety of practices as to type, length and criteria for their use. One road spiralled all curves in excess of 0-deg. 20 min., while the lower limit of curvature for the other roads varied all the way to 4-deg. The average ran at about 2-deg. Lengths varied widely, some roads using a fixed distance per degree of change, and others using a standard length without regard to degree of curve. It is estimated that about 25 percent of the railroad curves were spiraled at that date.

The Railway Age Gazette of June 17, 1910, contained an article which set forth the results of another questionnaire. Of 56 roads that replied, all except 5 were using easement curves. The Searles, Holbrook, Talbot, Hood and Stevens curves were most generally used. There was still a wide variation in the lengths of curves, but the majority used easements on all curves in excess of 2-deg. while a large number spiraled all curves in excess of 1-deg.

The Railway Age of April 15, 1921, carried an article, giving the results of still another questionnaire. Replies were received from 39 roads in the United States and Canada, representing an aggregate mileage of 190,000 miles, and it was found that all roads except one used spirals. The use was quite varied but is summarized as follows:—Used spirals on all lines, 4; on practically all lines, 9; on main lines and important branches, 2; on main lines, 7; on high-speed tracks, 6; "limited use", 1; replies indefinite, 9. There was also a wide variation as to the minimum degree of curvature for which it was deemed necessary to provide spirals. The replies are summarized as follows:—On all curves of 1-deg. or over, 11; curves of 1-deg. 30 min. or over, 1; curves of 1-deg. 45 min. or over, 1; curves of 2-deg. or over, 11. The replies from 6 other roads indicated a variation of practice depending on the class of track and degree of curve. The types of easement used are summarized as follows:—AREA, 2; Talbot, 11; Searles, 8; Holbrook, 2; Crandall, 2; Berry, 1; Stevens, 1; Sullivan, 1; Hood, 1; while the remaining roads used the general term cubic parabola, or indicated no preference at all. The replies as to the method of determining the length of spirals indicate that 25 roads considered both the degree of curve and speed of traffic, while 9 determined the length from the degree of curvature alone. Five of the replies were indefinite. All roads favored the employment of engineers for the application of the curves, and only

one road admitted the use of the string method of alinement, 28 roads using the deflection method, 4 the off-set method, two expressed no preference, and 4 gave indefinite replies.

A report presented at the second annual convention of the AREA (1901) stated that spirals were used by 14 out of 19 roads replying to a circular letter, and that one road had abandoned the use of easement curves after having found no particular advantage in their use. No conclusions were drawn; and no recommendations were made at this convention, but the report stated that generally easements were applied to all curves in excess of 2-deg. The report included an exposition of the Holbrook spiral, with tables for staking 60, 30 and 18-ft. spirals, the length referring to the distance in which a change of 1-deg. is obtained.

A report presented at the third annual convention (1902) recommended the spiraling of curves as follows:—For speeds not exceeding 30 m.p.h., all curves in excess of 2-deg.; for speeds not exceeding 60 m.p.h., all curves in excess of 1-deg.; and for higher speeds, all curves exceeding 0-deg. 30 min. The report recommended that the length of curve be the same as the superelevation runoff, and for ordinary practice a chord length of 100-ft. for each degree of variation, the chord to be shortened to 25-ft. or 30-ft. if necessary. The report further recommended that for very high speeds the chord length per degree of variation should be increased to 150-ft. or more, and further recommended the use of any curve of the Searles, Crandall, Holbrook, Talbot or cubic parabola types.

In the Proceedings for 1906, Vol. 7, there is a detailed outline of the easement curve with necessary formulas for the computation of the curve. The article is subdivided as follows;—

A. New Location
   1. Selecting the spiral. This paragraph discusses the length of spirals, and recommends the use of a length 600 times the superelevation.
   2. Location of the spiral.
      (a) By offsets—with an example.
      (b) By deflection angles—with an example.

B. The adjustment of existing tracks. It is recommended that the existing curve be compounded to obtain the proper "O" distance. In conclusion, there is a paragraph devoted to the installation of a spiral between compound curves. Four tables are included, as follows:
   1. Lengths of spirals connecting tangent and 1-deg. curve, for speeds of 20 to 90 m.p.h., showing 6 different lengths, from 100 to 600 times the superelevation.
   2. Table of corrections for half and whole tangent distances.
   3. Values of Δ, "O" and tangent offsets to connect a 1-deg. curve.
   4. Deflection angles to connect a 1-deg. curve.

The Proceedings for 1909, Vol. 10, Part 1, gave the result of a circular sent to members of the Association, and showed, as was expected, that practice varied widely. This report deals at great length with the spiral, and the reporting committee recommended some changes in the Manual, the most notable being that all curves elevated two inches or more should be spiraled.

The Proceedings for 1911, Vol. 12, Part 1, presented the ten-chord spiral, with arguments in its favor, notations, fundamental formulas, formulas for field use, method of staking by offsets, by deflections and tables. This ten-chord spiral was adopted.

In 1913 the "Table of functions of the ten-chord spiral" was submitted as supplementing and completing previous tables, and was adopted.

In 1914 the Committee on Track introduced information on the speed of trains through curves and level turnouts, with supporting formulas and tables. The committee recommended for adoption five diagrams of speeds of trains through curves and level

turnouts, and a table showing relative speeds through level turnouts, and in the report on Speeds of Trains on Curves and Turnouts, which was offered as information, speeds were all based on the use of an unbalanced elevation of three inches.

In 1936 two speed graphs that were adopted in 1914 were omitted from the new Manual and a new table introduced giving speed for equilibrium and three-inch unbalanced elevations.

Modern Practice

The operation of passenger trains at speeds of approximately 100 miles per hour warrants a careful study of curvature, including the amount of superelevation and the condition of transition between tangents and curve and between compound curves.

"Equilibrium Speed" on a superelevated curve is the speed at which the resultant of forces passes midway between the rails, and the lateral pressure against the rails is zero. If it were possible to operate all classes of traffic at the same speed around a curve, the ideal condition of smooth riding and minimum rail wear could be obtained by elevating for "equilibrium". However, a section of curve track must usually handle several classes of traffic operating at different speeds. A slow train passing over a curve that is elevated for a much higher speed tends to throw the track out of surface and to cause excessive wear on the inside rail.

Safety and comfort limit the speed at which a passenger train may negotiate a curve. Any speed that gives comfortable riding on a curve is well within the limits of safety. Experience has shown that the usual passenger coach, pullman car or lightweight equipment will ride comfortably around a curve at a speed which would require a superelevation about three inches higher for equilibrium. As far as high speed traffic is concerned, it may therefore be said that passenger comfort governs train speed on curves and that trains may be operated over curves at speeds somewhat greater than equilibrium speed. Advantage is taken of this condition in operating high-speed trains on track that must also carry slower traffic.

In order that there may be no disagreeable lurch when a train enters or leaves a curve, transition curves or spirals are inserted between the tangents and the circular curve. Within the length of each spiral the radius changes from infinity to the radius of the circular curve, or vice versa, and the superelevation changes from zero on the tangent to the full amount of the circular curve. If the transition is too short, the rapid change in elevation is uncomfortable to passengers. Spiral lengths on the basis of running out the elevation at a rate of 1¼ in. per sec. make comfortable riding for high speed traffic.

The Relation of Transition Curves to Speed and Superelevation

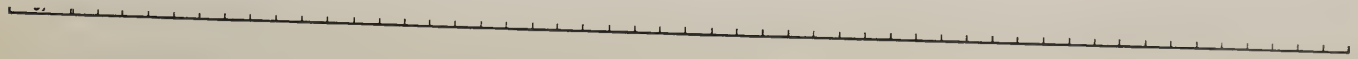
In appendix D of the committee's report on page 497, Vol. 39, reasons are given for the use as recommended practice of 3 in. unbalanced superelevation and a rate of 1¼ in. per sec. for the run-off of the transition curve. Committee 5—Track has recommended that the spiral curve be some form of the cubic parabola. Manual page 5–34.

The whole matter of degree of curve, superelevation, speed, tangent offset and length of transition curve is covered inflexibly and rather simply by five formulas:

For elevation, $E = \frac{S^2 D}{1{,}500} - 3$ ..... (1)

For permissible speed, $S^2 = \frac{1{,}500}{D}(E + 3)$ ..... (2)

For length of transition curve, $L = \frac{88ES}{75}$ ..... (3)



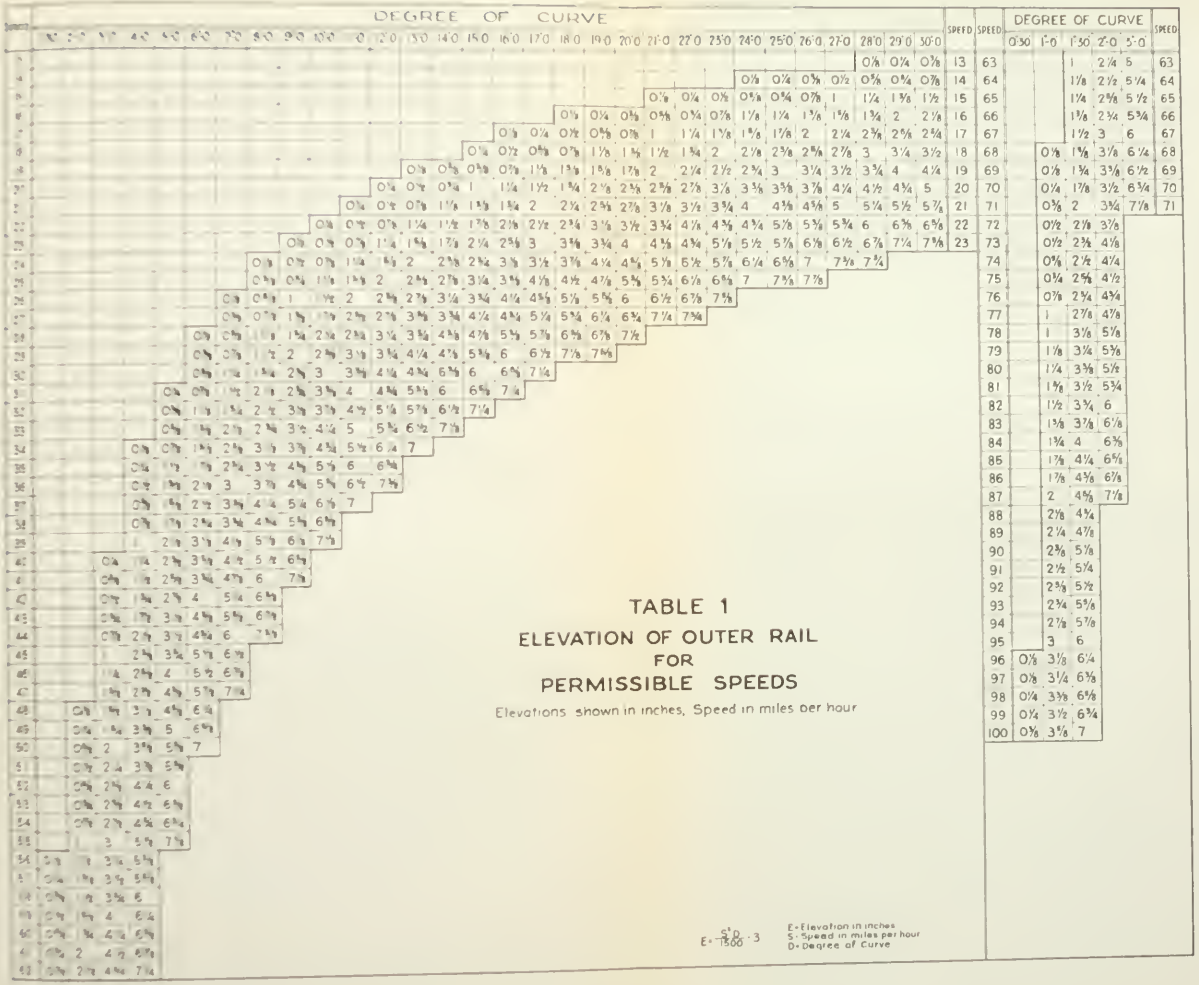

DEGREE OF CURVE
SPEED
DEGREE OF CURVE
SPEED
TABLE 1
ELEVATION OF OUTER RAIL
FOR
PERMISSIBLE SPEEDS
Elevations shown in inches. Speed in miles per hour
E = S²D / 1500 · 3
E - Elevation in inches
S - Speed in miles per hour
D - Degree of Curve

TABLE 2
PERMISSIBLE SPEEDS

$S^2 = \frac{1500}{D}(E+3)$

Elevations shown in inches. Speed in miles per hour

S = Miles per hour
E = Elevation in inches
D = Degree of Curve

ELEV.	0°-30'	0°-40'	0°-50'	1°-0'	1°-15'	1°-30'	1°-45'	2°-0'	2°-15'	2°-30'	2°-45'	3°-0'	3°-30'	4°-0'	5°-0'	6°-0'	7°-0'	8°-0'	9°-0'	10°-0'	11°-0'	12°-0'	13°-0'	14°-0'	15°-0'	16°-0'	17°-0'	18°-0'	19°-0'	20°-0'	ELEV.
½"	102	89	79	72	65	59	55	51	48	46	44	42	39	36	32	30	27	26	24	23	22	21	20	19	19	18	18	17	17	16	½"
¾"	106	92	82	75	67	61	57	53	50	47	45	43	40	38	34	31	28	27	25	24	23	22	21	20	19	19	18	18	17	17	¾"
1"	110	95	85	77	69	63	59	55	52	49	47	45	41	39	35	32	29	27	26	24	23	22	21	21	20	19	19	18	18	17	1"
1¼"	113	98	87	80	71	65	60	56	53	50	48	46	43	40	36	33	30	28	27	25	24	23	22	21	21	20	19	19	18	18	1¼"
1½"	116	101	90	82	73	67	62	58	55	52	50	47	44	41	37	34	31	29	27	26	25	24	23	22	21	21	20	19	19	18	1½"
1¾"	119	103	92	84	75	69	64	60	56	53	51	49	45	42	38	34	32	30	28	27	25	24	23	23	22	21	20	20	19	19	1¾"
2"	122	106	95	87	77	71	65	61	58	55	52	50	46	43	39	35	33	31	29	27	26	25	24	23	22	22	21	20	20	19	2"
2¼"		109	97	89	79	72	67	63	59	56	54	51	47	44	40	36	34	31	30	28	27	26	25	24	23	22	22	21	20	20	2¼"
2½"		111	99	91	81	74	69	64	61	57	55	52	49	45	41	37	34	32	30	29	27	26	25	24	23	23	22	21	21	20	2½"
2¾"		114	102	93	83	76	70	66	62	59	56	54	50	46	42	38	35	33	31	29	28	27	26	25	24	23	23	22	21	21	2¾"
3"		116	104	95	85	77	72	67	63	60	57	55	51	47	42	39	36	34	32	30	29	27	26	25	24	24	23	22	22	21	3"
3¼"		119	106	97	87	79	73	68	65	61	58	56	52	48	43	40	37	34	32	31	29	28	27	26	25	24	23	23	22	22	3¼"
3½"		121	108	99	88	81	75	70	66	62	60	57	53	49	44	40	37	35	33	31	30	29	27	26	25	25	24	23	23	22	3½"
3¾"			110	101	90	82	76	71	67	64	61	58	54	50	45	41	38	36	34	32	30	29	28	27	26	25	24	24	23	23	3¾"
4"			112	102	92	84	77	72	68	65	62	59	55	51	46	42	39	36	34	32	31	30	28	27	26	26	25	24	24	23	4"
4¼"			114	104	93	85	79	74	70	66	63	60	56	52	47	43	39	37	35	33	31	30	29	28	27	26	25	25	24	23	4¼"
4½"			116	106	95	87	80	75	71	67	64	61	57	53	47	43	40	38	35	34	32	31	29	28	27	27	26	25	24	24	4½"
4¾"			118	108	96	88	82	76	72	68	65	62	58	54	48	44	41	38	36	34	33	31	30	29	28	27	26	25	25	24	4¾"
5"			120	110	98	89	83	77	73	69	66	63	59	55	49	45	41	39	37	35	33	32	30	29	28	27	27	26	25	24	5"
5¼"				111	99	91	84	79	74	70	67	64	59	56	50	45	42	39	37	35	34	32	31	30	29	28	27	26	26	25	5¼"
5½"				113	101	92	85	80	75	71	68	65	60	56	50	46	43	40	38	36	34	33	31	30	29	28	27	27	26	25	5½"
5¾"				115	102	94	87	81	76	72	69	66	61	57	51	47	43	41	38	36	35	33	32	31	30	29	28	27	26	26	5¾"
6"				116	104	95	88	82	77	73	70	67	62	58	52	47	44	41	39	37	35	34	32	31	30	29	28	27	27	26	6"
6¼"				118	105	96	89	83	79	74	71	68	63	59	53	48	45	42	39	37	36	34	33	31	30	29	29	28	27	26	6¼"
6½"				119	107	97	90	84	80	75	72	69	64	60	53	49	45	42	40	38	36	34	33	32	31	30	29	28	27	27	6½"
6¾"				121	108	99	91	86	81	76	73	70	65	60	54	49	46	43	40	38	36	35	34	32	31	30	29	29	28	27	6¾"
7"					110	100	93	87	82	77	74	71	65	61	55	50	46	43	41	39	37	35	34	33	32	31	30	29	28	27	7"

TABLE 3
LENGTHS FOR TRANSITION CURVES

Elevations shown in inches, Lengths in feet

Length in feet = $L = \frac{88}{75} ES$

E = Elevation in inches

S = Permissible speed in miles per hour = $\sqrt{\frac{1500}{D}(E+3)}$

ELEV.	0°-30'	0°-40'	0°-50'	1°-0'	1°-15'	1°-30'	1°-45'	2°-0'	2°-15'	2°-30'	2°-45'	3°-0'	3°-30'	4°-0'	5°-0'	6°-0'	7°-0'	8°-0'	9°-0'	10°-0'	11°-0'	12°-0'	13°-0'	14°-0'	15°-0'	16°-0'	17°-0'	18°-0'	19°-0'	20°-0'	ELEV.
½"	60	52	47	43	38	35	32	30	28	27	26	25	23	21	19	17	16	15	14	13	13	12	12	11	11	11	10	10	10	10	½"
¾"	93	81	72	66	59	54	50	47	44	42	40	38	35	33	30	27	25	23	22	21	20	19	18	18	17	17	16	16	15	15	¾"
1"	129	111	100	91	81	74	69	64	61	57	55	52	49	45	41	37	34	32	30	29	27	26	25	24	23	23	22	21	21	20	1"
1¼"	166	143	128	117	105	96	89	83	78	74	71	68	63	59	52	48	44	41	39	37	35	34	32	31	30	29	28	28	27	26	1¼"
1½"	204	177	158	145	129	118	109	102	96	91	87	83	77	72	65	59	55	51	48	46	44	42	40	39	37	36	35	34	33	32	1½"
1¾"	245	212	190	173	155	142	131	123	116	110	105	100	93	87	78	71	66	61	58	55	52	50	48	46	45	43	42	41	40	39	1¾"
2"	287	249	223	203	182	166	154	144	135	129	123	117	109	102	91	83	77	72	68	64	61	59	56	54	52	51	49	48	47	45	2"
2¼"		287	257	234	210	191	177	166	156	148	141	135	125	117	105	96	89	83	78	74	71	68	65	63	60	59	57	55	54	52	2¼"
2½"		326	292	266	238	218	201	188	178	169	161	154	142	133	119	109	101	94	89	84	80	77	74	71	69	67	65	63	61	60	2½"
2¾"		367	328	300	268	245	227	212	200	190	181	173	160	150	134	122	113	106	100	95	90	87	83	80	77	75	73	71	69	67	2¾"
3"		409	366	334	299	273	252	236	223	211	201	193	178	167	149	136	126	118	111	106	101	96	93	89	86	83	81	79	77	75	3"
3¼"		452	404	369	330	301	279	261	246	234	223	213	197	185	165	151	140	131	123	117	111	107	102	99	95	92	90	87	85	83	3¼"
3½"		497	444	406	363	331	307	287	270	256	245	234	217	203	181	166	153	143	135	128	122	117	112	108	105	101	98	96	93	91	3½"
3¾"			485	443	396	361	335	313	295	280	267	256	237	221	198	181	167	157	148	140	133	128	123	118	114	111	107	104	102	99	3¾"
4"			527	481	430	393	364	340	321	304	290	278	257	240	215	196	182	170	160	152	145	139	133	129	124	120	117	113	110	108	4"
4¼"			570	520	465	425	393	368	347	329	314	300	278	260	233	212	197	184	173	164	157	150	144	139	134	130	126	123	119	116	4¼"
4½"			613	560	501	457	423	396	373	354	338	323	299	280	250	229	212	198	187	177	169	162	155	150	145	140	136	132	128	125	4½"
4¾"			658	601	537	491	454	425	401	380	362	347	321	300	269	245	227	212	200	190	181	173	167	161	155	150	146	142	138	134	4¾"
5"			704	643	575	525	486	454	428	406	388	371	344	321	287	262	243	227	214	203	194	186	178	172	166	161	156	151	147	144	5"
5¼"				685	613	560	518	485	457	433	413	396	366	343	306	280	259	242	228	217	207	198	190	183	177	171	166	162	157	153	5¼"
5½"				729	652	595	551	515	486	461	439	421	390	364	326	297	275	258	243	230	220	210	202	195	188	182	177	172	167	163	5½"
5¾"				773	691	631	584	547	515	489	466	446	413	386	346	316	292	273	258	244	233	223	214	207	200	193	187	182	177	173	5¾"
6"				818	732	668	618	578	545	517	493	472	437	409	366	334	309	289	273	259	247	236	227	219	211	204	198	193	188	183	6"
6¼"				864	773	705	653	611	576	546	521	499	462	432	386	353	326	305	288	273	260	249	240	231	223	216	210	204	198	193	6¼"
6½"				910	814	743	688	644	607	576	549	526	487	455	407	372	344	322	303	288	275	263	253	243	235	228	221	215	209	204	6½"
6¾"				958	857	782	724	677	639	606	578	553	512	479	428	391	362	339	319	303	289	276	266	256	247	239	232	226	220	214	6¾"
7"					900	821	760	711	671	636	607	581	538	503	450	411	380	356	335	318	303	290	279	269	260	251	244	237	231	225	7"

LENGTH OF TRANSITION (FEET)	DEGREE OF CURVE															LENGTH OF TRANSITION (FEET)
	0°-30'	0°-45'	0°-50'	1°-0	1°-15	1°-30	1°-45	2°-0	2°-15	2°-30	2°-45	3°-0	3°-30	4°-0	5°-0	
20	.002	.002	.003	.003	.004	.004	.005	.006	.007	.007	.008	.009	.010	.012	.015	20
40	.006	.006	0 0	.012	.015	.017	.020	.023	.026	.029	.032	.036	.041	.047	.058	40
60	.013	.014	.022	.026	.033	.039	.046	.052	.059	.065	.072	.079	.092	.105	.131	60
80	.023	.031	.039	.047	.058	.070	.081	.093	.105	.116	.128	.140	.163	.186	.233	80
100	.036	.049	.061	.073	.091	.109	.127	.145	.164	.182	.200	.218	.255	.291	.364	100
120	.052	.070	.087	.105	.31	.57	.183	.209	.236	.262	.288	.314	.367	.419	.524	120
140	.071	.095	.119	.143	.178	.214	.249	.285	.321	.356	.392	.428	.499	.570	.713	140
160	.093	.124	.155	.186	.233	.279	.326	.372	.419	.465	.512	.558	.652	.745	.931	160
180	.118	.157	.196	.236	.295	.353	.412	.471	.530	.589	.648	.707	.826	.942	1.178	180
200	.145	.194	.242	.291	.364	.436	.509	.582	.654	.727	.800	.873	1.018	1.164	1.454	200
220	.176	.235	.293	.352	.440	.528	.616	.704	.792	.880	.968	1.056	1.232	1.408	1.760	220
240	.209	.279	.349	.419	.524	.628	.733	.838	.942	1.047	1.152	1.257	1.466	1.675	2.094	240
260	.246	.328	.410	.492	.615	.737	.860	.983	1.106	1.229	1.352	1.475	1.721	1.966	2.458	260
280	.286	.380	.475	.570	.713	.855	.998	1.140	1.283	1.425	1.568	1.710	1.995	2.280	2.851	280
300	.327	.436	.545	.655	.818	.982	1.145	1.309	1.473	1.636	1.800	1.963	2.291	2.618	3.272	300
320	.372	.496	.621	.745	.931	1.117	1.303	1.489	1.675	1.862	2.048	2.234	2.606	2.979	3.723	320
340	.420	.560	.701	.841	1.05	1.261	1.471	1.681	1.891	2.102	2.312	2.522	2.942	3.362	4.203	340
360	.471	.628	.785	.942	1.178	1.414	1.649	1.885	2.120	2.356	2.592	2.827	3.298	3.770	4.712	360
380		.700	.875	1.050	1.313	1.575	1.838	2.100	2.363	2.625	2.888	3.150	3.675	4.200	5.250	380
400		.776	.970	1.164	1.454	1.745	2.036	2.327	2.618	2.909	3.200	3.490	4.072	4.654	5.817	400
420		.855	1.069	1.283	1.603	1.924	2.245	2.565	2.886	3.207	3.528	3.848	4.490	5.131	6.414	420
440		.939	1.173	1.408	1.760	2.112	2.464	2.816	3.168	3.520	3.872	4.225	4.927	5.631	7.039	440
460		1.026	1.282	1.539	1.923	2.308	2.693	3.077	3.462	3.847	4.232	4.616	5.385	6.156	7.693	460
480		1.117	1.396	1.675	2.094	2.513	2.932	3.351	3.770	4.189	4.607	5.026	5.864	6.702	8.377	480
500		1.212	1.515	1.818	2.272	2.727	3.181	3.636	4.090	4.545	4.999	5.454	6.363	7.272	9.090	500
520		1.311	1.639	1.966	2.458	2.950	3.441	3.933	4.424	4.916	5.407	5.899	6.882	7.865	9.831	520
540		1.414	1.767	2.120	2.651	3.181	3.711	4.241	4.771	5.301	5.831	6.361	7.422	8.482		540
560		1.520	1.900	2.280	2.851	3.421	3.991	4.561	5.131	5.701	6.271	6.841	7.981	9.122		560
580		1.631	2.039	2.446	3.058	3.669	4.281	4.892	5.504	6.116	6.727	7.339	8.562	9.785		580
600			2.182	2.618	3.272	3.927	4.581	5.236	5.890	6.545	7.199	7.853	9.162			600
620			2.329	2.795	3.494	4.193	4.892	5.590	6.289	6.988	7.687	8.386	9.785			620
640			2.482	2.979	3.723	4.468	5.212	5.957	6.702	7.446	8.191	8.935				640
660			2.640	3.168	3.959	4.751	5.543	6.335	7.127	7.919	8.711	9.503				660
680			2.802	3.362	4.203	5.044	5.884	6.725	7.565	8.406	9.247					680
700			2.969	3.563	4.454	5.345	6.235	7.126	8.017	8.908	9.799					700
720			3.141	3.770	4.712	5.654	6.597	7.539	8.482	9.424						720
740			3.318	3.982	4.978	5.973	6.969	7.964	8.959	9.955						740
760			3.500	4.200	5.250	6.300	7.350	8.400	9.450							760
780				4.424	5.530	6.636	7.742	8.848	9.954							780
800				4.654	5.817	6.981	8.144	9.308								800
820				4.890	6.112	7.334	8.557	9.779								820
840				5.131	6.414	7.696	8.979									840
860				5.378	6.723	8.067	9.412									860
880				5.631	7.039	8.447										880
900				5.890	7.363	8.835										900
920				6.156	7.693											920
940				6.425	8.032											940
960				6.702												960
980				6.984												980
1000				7.272												1000

LENGTH OF TRANSITION (FEET)	DEGREE OF CURVE															LENGTH OF TRANSITION (FEET)
	6°-0	7°-0	8°-0	9°-0	10°-0	11°-0	12°-0	13°-0	14°-0	15°-0	16°-0	17°-0	18°-0	19°-0	20°-0	
20	.018	.020	.023	.026	.029	.032	.035	.038	.041	.044	.047	.049	.052	.056	.058	20
40	.070	.081	.093	.105	.116	.128	.140	.151	.163	.175	.186	.198	.209	.221	.233	40
60	.157	.183	.210	.236	.262	.288	.314	.340	.367	.393	.419	.446	.471	.498	.524	60
80	.279	.326	.372	.419	.465	.512	.559	.605	.652	.698	.745	.791	.838	.884	.931	80
100	.436	.509	.582	.654	.727	.800	.873	.945	1.018	1.091	1.164	1.236	1.309	1.382	1.454	100
120	.628	.733	.838	.942	1.047	1.152	1.257	1.361	1.466	1.571	1.675	1.780	1.885	1.990	2.094	120
140	.855	.998	1.140	1.283	1.425	1.568	1.710	1.853	1.995	2.138	2.280	2.423	2.565	2.708	2.851	140
160	1.117	1.303	1.489	1.675	1.862	2.048	2.234	2.420	2.606	2.792	2.978	3.165	3.351	3.537	3.723	160
180	1.414	1.649	1.886	2.120	2.356	2.592	2.827	3.063	3.298	3.534	3.770	4.005	4.241	4.476	4.712	180
200	1.745	2.036	2.327	2.618	2.909	3.200	3.491	3.781	4.072	4.363	4.654	4.945	5.236	5.526	5.817	200
220	2.112	2.464	2.816	3.168	3.520	3.871	4.223	4.575	4.927	5.279	5.631	5.983	6.335	6.687	7.039	220
240	2.513	2.932	3.351	3.770	4.189	4.607	5.026	5.445	5.864	6.283	6.702	7.120	7.539	7.958	8.377	240
260	2.949	3.441	3.933	4.424	4.916	5.407	5.899	6.390	6.882	7.373	7.865	8.357	8.848	9.340	9.831	260
280	3.421	3.991	4.561	5.131	5.701	6.271	6.841	7.411	7.981	8.552	9.122	9.692	10.262	10.832		280
300	3.927	4.581	5.236	5.890	6.545	7.199	7.853	8.508	9.162	9.817	10.471					300
320	4.468	5.212	5.967	6.702	7.446	8.191	8.935	9.680	10.425							320
340	5.044	5.884	6.725	7.565	8.406	9.247	10.087									340
360	5.654	6.597	7.539	8.482	9.424	10.366										360
380	6.300	7.350	8.400	9.450	10.500											380
400	6.981	8.144	9.308	10.471												400
420	7.696	8.979	10.262													420
440	8.447	9.855														440
460	9.232															460

TABLE 4

OFFSETS FOR TRANSITION CURVES

OFFSET = .0000072717 LD

TABLE 5
OFFSETS & ORDINATES
Elevations shown in inches, Offsets and Ordinates in feet

ELEV.	ORD. N°1	ORD. N°2	ORD. N°3	ORD. N°4	ORD. N°5	ELEV.	OFFSET 'O'
½			.001	.003	.007	½	.013
¾		.001	.003	.008	.016	¾	.032
1		.002	.007	.016	.030	1	.060
1¼		.003	.011	.026	.050	1¼	.100
1½	.001	.005	.016	.039	.076	1½	.152
1¾	.001	.007	.024	.056	.109	1¾	.218
2	.001	.010	.032	.077	.150	2	.300
2¼	.002	.013	.043	.102	.200	2¼	.399
2½	.002	.017	.056	.132	.258	2½	.516
2¾	.003	.021	.071	.167	.326	2¾	.653
3	.003	.026	.088	.208	.405	3	.811
3¼	.004	.032	.107	.254	.496	3¼	.991
3½	.005	.038	.129	.306	.598	3½	1.196
3¾	.006	.046	.154	.365	.713	3¾	1.426
4	.007	.054	.182	.431	.841	4	1.682
4¼	.008	.063	.212	.503	.983	4¼	1.966
4½	.009	.073	.246	.584	1.140	4½	2.281
4¾	.011	.084	.284	.672	1.313	4¾	2.626
5	.012	.096	.324	.769	1.502	5	3.003
5¼	.014	.109	.369	.874	1.707	5¼	3.415
5½	.015	.124	.417	988	1.931	5½	3.861
5¾	.017	.139	.469	1.112	2.172	5¾	4.344
6	.019	.156	.525	1.246	2.433	6	4.865
6¼	.022	.174	.586	1.389	2.713	6¼	5.426
6½	.024	.193	.651	1.543	3.014	6½	6.027
6¾	.027	.213	.720	1.708	3.335	6¾	6.671
7	.029	.235	.795	1.884	3.679	7	7.358

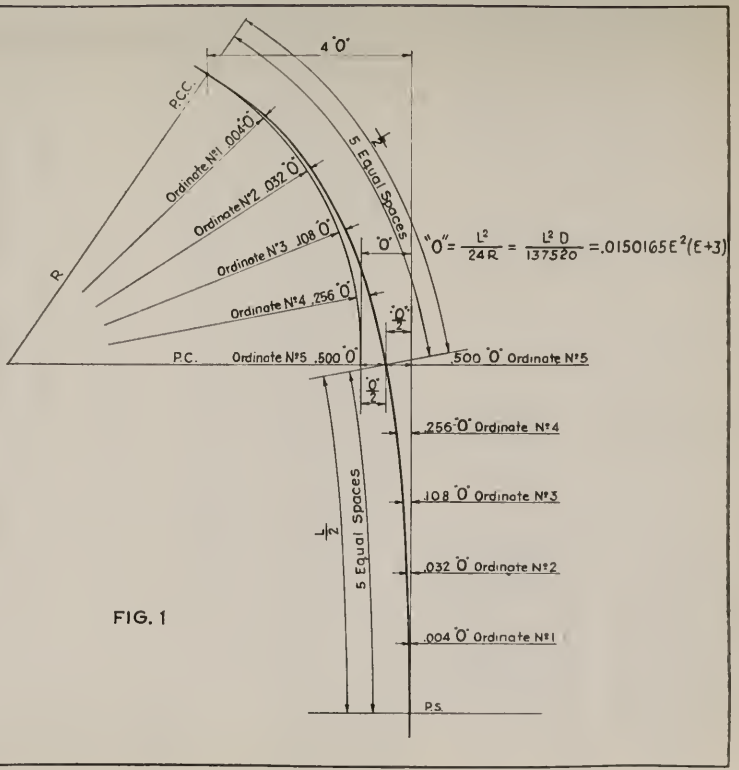


FIG. 1

For the offset between tangent and circular curve,

$$O = \frac{L^2}{24R} = \frac{L^2 D}{137{,}520} \quad \ldots\ldots (4)$$

For ordinates from tangent or circular curve to transition curve, $y = \frac{x^3}{6LR} = \frac{Dx^3}{34{,}380L}$ ..... (5)

in which E = elevation in inches
S = speed in miles per hour
D = degree of curve
L = length of transition curve in feet
O = offset in feet
x = abscissa in feet
y = ordinate in feet

The derivation of these formulas is as follows:

Formula (1)

Committee 5—Track, Manual page 5–42 gives $E = .00066S^2D - 3$. This results from the use of 56½ in. for the horizontal distance between points of contact of wheel and rail. This distance should be somewhat greater. The use of 57.11 in. gives the reciprocal of 1,500, or .0006667, for the decimal portion of the formula, hence the simple form

$$E = \frac{S^2D}{1{,}500} - 3, \text{ is more nearly correct.}$$

Formula (2)

This results from a simple transposition of Formula (1).

Formula (3)

Using the rate of 1¼ in. per sec., we have—Number of Seconds $= \frac{E}{1.25} = \frac{4E}{5}$. If V = velocity in feet per second $= \frac{22S}{15}$, L = Number of seconds times feet per second = $\frac{4E}{5}$ times $\frac{22S}{15} = \frac{88ES}{75}$.

Formula (4)

The Froude formula for transition curves starts with an offset equal to $\frac{L^2}{24R}$. Taking $D = \frac{5{,}730}{R}$ this becomes $\frac{L^2D}{137{,}520}$. Substituting for L its value $\frac{88ES}{75}$ from (3) we have $O = \frac{88^2}{75^2}$ times $\frac{E^2S^2D}{137{,}520}$ and substituting for S^2 its value $\frac{1{,}500\,(E+3)}{D}$ we have $O = \frac{88^2}{75^2}$ times $\frac{1{,}500E^2\,(E+3)}{137{,}520}$. This expression reduces numerically to the value, $0.0150165E^2$ $(E+3)$, is independent of the degree of curve, and has been used in the computation of the offsets in Table 5, corresponding to the lengths and elevations of Table 3.

Formula (4), as given, reduces to the decimal form $O = 0.00000727167L^2D$, and this value has been used in the computation of Table 4.

Formula (5)

Fig. 1 shows the relations existing in the Froude curve which is approximately a cubic parabola, the approximation consisting in the assumption that the tangent, arc, and chord of the circular curve are sensibly equal. The transition curve bisects the main offset at the P.C. and is itself bisected at that point. The ordinates to the transition curve from the tangent and from the circular curve vary as the cubes of the distances from the tangent point and the deflections vary as the squares of those distances.

The equation of the curve with origin at the P.S.C. is $y = \frac{x^3}{6LR} = \frac{Dx^3}{34{,}380L}$. This equation permits of the location of points on the curve by ordinates from the tangent or from the circular curve but for simplicity, Table 5 has been computed by dividing the curve into ten equal stations as shown in Fig. 1. In this figure the ordinates for all of the stations are given in terms of the offset.

The procedure outlined herein permits wide latitude in adjusting the features of degree of curve, amount of superelevation, permissible speed, length of transition curve, and offset of tangent from circular curve—whichever one of these features may be the limiting one in any case. The simple but inflexible relations insure against both extravagance and inadequacy in one feature in the face of fixed conditions affecting another feature.

For example, usually the degree of curve is given and a desired permissible speed is chosen. These two features fix the elevation, the elevation fixes the offset, and the degree of curve and the elevation together fix the length of the transition curve. If it so happens that conditions at the site limit the offset, a different elevation and, consequently, a different permissible speed must be chosen. Again, if conditions such as preponderance of freight traffic limit the amount of superelevation, the speed must be reduced and obviously nothing would be gained by a longer transition curve or greater offset.

Because there is some flexibility in the permissible rate of run-off of the elevation, Table 4 will permit of the selection of a length reasonably greater or less than that fixed by the formula and Table 3.

It is recommended that this report be received as information.

Appendix J

(12) GRADES AND ALINEMENT THROUGH TUNNELS

F. N. Nye, Chairman, Subcommittee; J. L. Campbell, E. B. Crane, H. H. Edgerton, J. L. Haugh, R. J. Herring, Wm. Michel, L. G. Morphy, B. H. Prater, H. M. Shepard, C. K. Smith, C. B. Stanton, W. D. Wiggins, S. L. Wonson.

In carrying forward this assignment, the subcommittee prepared a comprehensive questionnaire designed to elicit information covering not only the problem of tunnel location and the relation of the tunnel to other parts of the railway line, but also certain conditions of operation through tunnels. This questionnaire was addressed to chief engineers of the major railroads of the United States, Canada and Mexico, and embraces all tunnels 1,000 ft. or more in length. The response to this questionnaire to date has been very satisfactory. Seventy-three replies have been received which may be summarized as follows:

41 railroads report no tunnels of 1,000 ft. or greater length.
30 railroads have furnished the requested data covering 215 tunnels in this category.
2 railroads report they are preparing replies.
Over 40 railroads have as yet not had the opportunity to reply.

The data received are being tabulated and when assembled will be analyzed in order to enable the committee to formulate recommendations as to tunnel location, taking into account certain operating conditions and location characteristics as determined from a study of existing tunnels of this magnitude.

It is recommended that this review of progress be received as information.

Appendix K

(13) ECONOMICS OF RAILWAY LOCATION AS AFFECTED BY RAILWAY ELECTRIFICATION

E. E. King, Chairman, Subcommittee; B. T. Anderson, V. T. Boughton, H. C. Crowell, L. E. Dale, F. N. Nye, J. R. Scatterday, H. W. Snyder, C. B. Stanton, H. M. Stout, W. D. Wiggins, H. W. Williams.

This year the subcommittee has been engaged in bringing together data on the principal characteristics of steam railroad electrifications in the United States and Canada. These data are shown in Table I. They carry on up to the end of 1937 the figures compiled for these two countries by the Railway Electrification Committee of the National Electric Light Association, as indicated in its last report, Publication No. 247, March, 1933, "Electrification of Steam Railways", and by the Federal Power Commission in connection with the National Power Survey as reported in its publication of May, 1936, "The Use of Electric Power in Transportation."

The complete report prepared by the committee of the National Electric Light Association contains data on steam railroad electrification of all lines in the world and includes more detail concerning the electrified systems than can be presented in this report. The report of your committee was prepared by compiling certain data from these two reports and sending them to the railroads concerned to have the figures brought up to date as of the end of 1937. The material in this report is, therefore, a portion of the data in these two reports, revised to correspond with present operating conditions. Permission was obtained from these two committees to use their materials in this way for which acknowledgment is made here.

At the end of 1937, according to Table I, there were 31 route miles and 40 track miles of electrified lines on the railroads in Canada and 2,697 route miles and 6,304 track miles on the railroads in the United States. Besides showing the number of miles electrified, Table I shows the locations of the electrified sections, and also information concerning tunnels and ruling grades, the systems of electrification and the kinds of traffic electrified, the weight of the heaviest motive power, energy requirements, the reasons for electrification, and other important characteristics. As the table indicates, many of the sections were electrified to simplify the smoke problem in tunnels or terminal regions. Other sections were electrified for economy of operation over heavy grades and where regenerative braking was a factor for consideration. Still other sections were electrified for economy of operation through territory where density of traffic was the chief point of consideration.

During the earlier installations of electric power in steam railroad electrifications there does not seem to have been much uniformity of systems in common practice, but during more recent transformations the tendencies have been towards the use of 11,000-volt, 25-cycle, single-phase alternating current and 3,000-volt, direct current, both with overhead contact systems. In most of the recent installations of electric power in suburban service, where acceleration is a matter of serious concern, multiple-unit motor-car trains have been employed. In the case of through freight and passenger as well as switching service, trains are usually handled by electric locomotives.

The table shows four lines on the Eastern region of the Pennsylvania Railroad in process of electrification, but which had not yet advanced to the point of electric operation at the end of 1937.

In 1907, the Erie Railroad electrified the 34 miles of its line between Rochester and Mount Morris, New York, for the benefit of local passenger service between these points. The system was 25-cycle, single-phase current with overhead contact lines. Through

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TABLE I PRINCIPAL CHARACTERISTICS OF STEAM RAILROAD ELECTRIFICATIONS IN THE UNITED STATES AND CANADA, DECEMBER, 1937

Name of Railway	Location of Electrified System	Miles Electrified: Route	Miles Electrified: Track (Tracks)	Ruling Grade Against Traffic: %	Ruling Grade Against Traffic: Length, Feet	Tunnels: No.	Tunnels: Total Length, Feet	System of Electrification: Current	Volts	Phase	Cycles	Contact Line	Year Electric Operation Began	Electric Motive-Power Equipment: Passenger Locomotives: No.	Passenger Locomotives: Largest Type: Weight, Lb.	Tractive Effort, Lb.	H.P. (1 Hour Rating)	Freight Locomotives: No.	Freight Locomotives: Largest Type: Weight, Lb.	Tractive Effort, Lb.	H.P. (1 Hour Rating)	Switching Locomotives: No.	Switching Locomotives: Largest Type: Weight, Lb.	Tractive Effort, Lb.	H.P. (1 Hour Rating)	Passenger Motor Cars: No.	Passenger Motor Cars: Largest Type: Weight, Lb.	H.P.	Motors per Car	Average No. of Trains Daily: Pass.	Average No. of Cars per Train: Pass.	Average No. of Cars per Train: Frt.	Kw. Hrs. of Energy Supplied in 1937: Gener-ated	Kw. Hrs. of Energy Supplied in 1937: Purchased	Max. Load of Gen. and Pur. Power, Kw. in 1937	Principal Reasons for Electrification
Canada																																				
Canadian National Rys.	Sarnia-Cut to Port Huron, Mich.	4	6	16	2.00	5,185	1	12,050	AC	3300	1	25	OH	1908	69	413,000	21,184	952	—	—	—	—	—	—	—	—	—	—	—	8	28	6	34	—	4,886,165	3,500	Heavy grades, eliminate smoke in tunnel, increase capacity
Canadian Pacific Rys.	Montreal-Cartierville, St. Eustache	18	23	36	0.60	15,634	1	33,305	DC	2400	—	—	OH	1918	6	160,000	30,200	1280	—	—	—	—	—	—	—	—	—	—	—	3	9	3	3	—	2,906,340	1,800	Tunnel operation, residential section
Montreal Harbour Comm.	Montreal Harbour	9	—	40	0.00	—	0	—	DC	2400	—	—	OH	1924	—	—	—	—	—	—	—	—	—	—	9	220,000	43,000	1600	—	—	—	—	—	—	—	—	—
Total		31		92																																
United States																																				
Baltimore & Ohio R.R.	Baltimore Belt Line (Originally overhead. Changed to 3rd rail in 1935)	4	9	9	1.32	1000	9	9,530	DC	650	—	—	3R	1895	118	240,000	32,000	1100	See note d" below											24	18	8	60	(2)	5,434,000	6000	City ordinance elimination of smoke in tunnel, increase capacity, lower cost
Baltimore & Ohio R.R.	Staten Island Rapid Transit Lines	22	43	50	1.82	3000	1	609	DC	650	—	—	3R	1925	—	—	—	—	—	—	—	—	—	—	—	—	—	90	93,730	400	2	468	—	2	—	15,651,530	3,900	City ordinance, improve service
Beaumont, Sour Lake & Western Ry.	Houston to Goose Creek, Texas	28	28	36	0.40	3000	0	-	DC	600	—	—	OH	1927	—	—	—	—	—	—	—	—	—	—	2	50,000	25,000	400	5	66,000	140	4	40	2	—	12	1,362,800	478	
Boston & Maine R.R.	Hoosac Tunnel, Mass.	8	18	21	0.75	9,500	1	30,180	AC	11000	1	25	OH	1911	1017	283,500	18,480	1360	—	—	—	—	—	—	—	—	—	—	—	10	18	7	72	—	12,147,616		Eliminate smoke in tunnel; increase capacity
Boston, Revere Beach & Lynn R.R.	East Boston to Lynn and Waltham, Mass.	14	28	31	0.50	250	2	1000	DC	650	—	—	OH	1928	—	—	—	—	—	—	—	—	—	—	—	—	—	80	53,000	120	2	88	—	3	—	4,998,700	2,839	Increase capacity, reduce operating cost
Butte, Anaconda & Pacific Ry.	Butte to Anaconda, Montana	37	60	122	0.30	3,680	5	1,656	DC	2400	—	—	OH	1913	—	160,500	20,000	1116	28	160,500	30,000	1116	—	—	—	—	—	—	—	4	1	—	120	—	20,213,208	7,680	Increase capacity, general economy
Chicago, Milwaukee, St. Paul & Pacific R.R.	Harlowton, Mont. to Avery, Idaho	441	441	380	1.70	118,160	33	29,515	DC	3000	—	—	OH	1915-16	9	620,000	66,000	4200	12	864,000	126,750	5100	6	288,000	42,250	1720	—	—	—	—	—	—	—	—	—	Increase capacity, general economy, heavy grades, tunnels
	Othello to Seattle and Tacoma, Wash.	218	230	906	2.20	80,780	8	18,712	DC	3000	—	—	OH	1919-27	5	321,000	48,300	3300	24	576,000	84,500	5440	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chicago Union Transfer R.R. Co.	Clearing and Terminal Cleveland, Ohio	17	33	36	1.38	2600	0	-	DC	3000	—	—	OH	1929	22(1)	418,000	75,000	3050	—	—	—	—	—	—	—	—	—	—	—	112	—	11	—	—	18,778,000	4700	City ordinance, eliminate smoke, air rights at station
Chicago, Lackawanna & Western R.R.	Hillsdale Freight Term. not Brooklyn	0	0	1	—	—	—	—	DC	800	—	—	OH	1926	—	—	—	—	—	—	—	—	1	102,840	—	—	220	—	—	—	—	—	—	—	60,000	180	City ordinance
	Hoboken to Edgestone, Dover - Montclair, N.J.	70	133	160	1.60	7960	1	17,132	DC	3000	—	—	OH	1930-31	—	—	—	—	—	—	—	—	—	—	—	—	—	141	148,400	940	4	242	—	4.67	—	34,647,930	19,572	Improve service, increase capacity, tunnel
Chicago, Rock Island & Southern (a)	Des Moines to Ft. Dodge - Russell City, Ia.	147	147	195	1.30	6600	0	-	DC	1200	—	—	OH	1906-12	—	—	—	—	13	150,000	24,240	1200	—	—	—	—	—	—	12	64,000	300	—	—	—	—	—	—	Improve service, general economy
Great Northern Ry.	Wenatchee to Skykomish, Wash. (Old Cascade Tunnel electrified in 1909 with 3 phase power, changed in 1927 to 1 phase power and line extended. New tunnel with extension opened in 1929 and old tunnel abandoned.)	73	73	94	2.20	53,680	8	48,600	AC	11000	1	25	OH	1927-29	8	527,200	67,200	3300	6	363,740	56,250	2,185	—	—	—	—	—	—	—	6	3.1	10.	105	—	31,293,000	12,440	Eliminate smoke in tunnel, general economy, increase speed of trains
Illinois Central R.R.	Chicago to Kickton and branches	36	112	136	0.53	3840	1	1080	DC	1300	—	—	OH	1926-28	—	—	—	—	—	—	—	—	8	195,000	31,000	1800	140	142,700	1000	4	327	—	3.75	—	38,084,857	23,811	City ordinance, eliminate smoke, improve service
Illinois Terminal R.R.	St. Louis, Mo. to Peoria & Pawnee, Ill.	431	448	504	2.60	5250	0	-	DC	650	—	—	OH	1900	—	—	—	—	20	160,000	21,250	1000	20	166,500	24,804	1000	52	122,000	800	4	54	33	2	24	—	33,941,000	9500	
Long Island R.R.	New York and Brooklyn to Western Port of Long Island	120	200	365	2.00	1500	2	10,240	DC	650	—	—	3R	1905-27	19	313,000	88,000	1580 cont	—	—	—	—	2	50,000	15,000	85 cont	1005	117,500	670	2	—	—	—	—	181,333,087		Improve suburban service, tunnels
	Bay Ridge to Fresh Pond Jct. N.Y.	12	38	82	0.70	7500	1	3540	AC	11000	1	25	OH	1927	—	—	—	—	—	—	—	—	14	138,000	30,000	570	—	—	—	—	—	—	—	—	—		Facilitate thru operation into N.Y.W.H.&H.R.R. eliminate smoke, gas, etc.
Michigan Central R.R. (N.Y.C.)	Detroit Mich. to Windsor, Ontario	5	9	29	2.00	2149	1	8,390	DC	650	—	—	3R	1910	6(1)	242,300	60,000	1120	—	—	—	—	—	—	—	—	—	—	—	28	65	9	5.5	—	3,941,846	2204	
New York Central R.R.	New York to Croton - White Plains, N.Y.	70	227	381	1.07	3826	2	14,400	DC	650	—	—	3R	1906-27	98	292,600	18,400	2438	64	354,000	55,800	3320	82	229,900	13,700	1863	351	140,000	600	2	550(3)		26(30)	—	176,568,362	7,024	Tunnel operation, improve service, city ordinance, air rights
New York Connecting R.R.	Port Morris to Bay Ridge, N.Y.	21	40	63	1.28	1000	2	770	AC	11000	1	25	OH	1927	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		Faraway electric service in city
New York, New Haven & Hartford (Several sections electrified between 1905 and 1908 with 3rd rail or trolley at 600 V were later removed because of legislation against 3rd rail or at request in traffic)	New York to Woodlawn, N.Y. (Charates over tracks of N.Y.C.)	12	49	78					DC	650	—	—	3R	1907	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
	Woodlawn N.Y. to New Haven, Conn. and branches to Harlem River, New Canaan, Danbury, etc.	116	381	377	1.00	880	1	330	AC	11000	1	25	OH	1907-27	59	432,000	68,300	3800	43	482,000	30,000	1618	24	221,300	42,000	694	76	160,000	1040	4	—	—	—	—	—	—		Increase capacity, general economy
	Harlem River, Port Chester, White Plains N.Y. (New York Westchester & Boston Ry. discontinued service in 1937)				1.39	1000	1	4000	AC	11000	1	25	OH	1912-29	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
	Providence, Warren, Bristol, Fall River (Discontinued in 1938)	24	61	62	1.28	1058	1	3080	DC	650	—	—	OH	1201	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Improve service
Norfolk & Western Ry.	Bluefield to Tioget, W.Va. and branches	77	136	208	2.00	83,160	20	29,820	AC	11000	1	25	OH	1915-25	—	—	—	—	18	632,000	108,000	4,750	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Tunnels, heavy grades, increase capacity
Norfolk Southern R.R. Co.	Norfolk to Cape Henry - Virginia Beach	44	50	68					DC	600	—	—	OH	1915	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Improve service
Northwestern Pacific R.R. (a)	Sausalito, San Anselmo, San Raphael, Calif. and branches	21	36	42	—	—	2	3310	DC	600	—	—	3R	1903	—	—	—	—	—	—	—	—	—	—	—	—	—	56	111,520	508	4	—	—	—	—	—		Improve suburban passenger service
Pennsylvania R.R.	New York to Pool, Pa. and Washington, D.C. (New York to Manhattan Transfer, N.J. Electrified in 1910 with 675 V. 3rd rail and changed in 1935 to present power)	380	1069	1368			12	74,082	AC	11000	1	25	OH	1933	106	480,000	72,800	4830 cont	70	447,800	80,000	3300 cont	28	137,045	52,000	370 cont	432 (7)	127,000	740 cont	2	—	—	—	—	38,416,200	522,962,178	
	Pool to Harrisburg	Not in service during 1937							AC	11000	1	25	OH																							
	Marysville, Pa. via Columbia to Lewis Yard	"	"	"	"				AC	11000	1	25	OH																							
	Columbia, Pa. to Perryville, Md.	"	"	"	"				AC	11000	1	25	OH																							
	Monmouth Jct. to South Amboy, N.J.	"	"	"	"				AC	11000	1	25	OH																							
	Philadelphia Suburban	Included above							AC	11000	1	25	OH	1915-30																							
Pennsylvania-Reading Seashore Lines	Camden to Millville, N.J.	44	68	76					DC	650	—	—	3R	1908	—	—	—	—	—	—	—	—	—	—	—	—	—	53	106,000	360	2	—	—	—	—	18,859,000	4902	Improve service
Reading Co.	Philadelphia District	84	182	198	1.39	12,500	—	—	AC	11000	1	25	OH	1931	—	—	—	—	—	—	—	—	—	—	—	—	—	100	147,000	680	2	276	—	1.92	—	31,390,910	11,578	
Southern Pacific Co.	Oakland, Alameda, Berkeley, Calif.	38	73	114	3.53	200	1	463	DC	1200	—	—	OH	1911	—	—	—	—	—	—	—	—	—	—	—	—	—	27	117,400	580	4	64.2	—	2	—	62,620,000	—	Improve service, eliminate smoke
Virginian Ry.	Roanoke, Va. to Mullins, W.Va.	135	138	465	2.07	63,360	19	10,956	AC	11000	1	25	OH	1925-26	—	—	—	—	14	1,264,360	162,000	7,125	—	—	—	—	—	—	—	—	13	—	77	104,304,000	—	63,800	Increase capacity, heavy grades, tunnels
Total		2607		6304																																

(a) Characteristics as given by the Com. of N.E.L.A. for 1938.

(b) Characteristics as given by the Com. of N.E.L.A. for 1931.

(c) Characteristics as given by the Federal Power Com. for 1936.

(d) Passenger and Freight.
(3) Also used in Terminal Switching Service.

(e) Includes 253 Trailers
(f) Includes 48 Trailer Cars

(g) Electric Operation Eastbound Only

(h) Approx. only. Includes N.Y.C.H.&H.R.R.
(2) Flyovers with Traffic & Type of Service

METALLURGY

passenger and freight trains continued to be operated by steam power. The electric service was discontinued on this line in 1934, because of decline in traffic, and its characteristics are, therefore, not included in Table I.

The 75 route miles of the Pennsylvania-Reading Seashore Lines from Camden to Atlantic City, N. J., electrified in 1906, with 650-volt, d.c. power were recently discontinued. Electric operation in the Great Falls yard of the Chicago, Milwaukee, St. Paul & Pacific Railroad comprising four route miles and seven track miles of line was also recently discontinued. The yard was electrified in 1915 with 1,500-volt d.c. power and overhead contact line. Both of these cases are omitted in Table I.

The reports include studies only on those lines that were at one time operated wholly or in part by steam power, but which are now operated in part, at least, by electric power supplied from a central electric plant.

Portions of two steam railroad lines in Mexico are operated by electric power, and it is the purpose of the subcommittee to prepare in the immediate future a report for the Association that will include the characteristics of these two lines.

The subcommittee recommends that the materials contained in this report be received as information.

REPORT OF COMMITTEE 10—SIGNALS AND INTERLOCKING

H. G. Morgan, *Chairman;*
F. H. Bagley,
G. H. Dryden,
W. J. Eck,
W. H. Elliott,
P. M. Gault,
C. R. Hodgdon,
S. N. Mills,
J. C. Mock,
R. D. Moore,
F. W. Pfleging,
W. M. Post,
A. H. Rudd,
J. E. Saunders,
H. L. Stanton,
E. G. Stradling,
H. H. Orr, *Vice-Chairman;*
C. A. Taylor,
G. K. Thomas,
C. H. Tillett,
W. M. Vandersluis,
F. B. Wiegand,
L. Wyant,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Developments in railway signaling (Appendix A). Progress report.

2. The principal current activities of the Signal section, AAR, by synopsis, supplemented with list and references by number of adopted specifications, designs and principles of signaling practice (Appendix B). Progress report.

The Committee on Signals and Interlocking,
H. G. Morgan, *Chairman.*

Appendix A

(1) DEVELOPMENTS IN RAILWAY SIGNALING

W. M. Post, Chairman, Subcommittee; G. H. Dryden, W. J. Eck, J. C. Mock, C. A. Taylor, C. H. Tillett.

There have been no developments since those reported to the annual meeting in 1938.

Appendix B

(2) THE PRINCIPAL CURRENT ACTIVITIES OF THE SIGNAL SECTION, AAR, BY SYNOPSIS, SUPPLEMENTED WITH LIST AND REFERENCES BY NUMBER OF ADOPTED SPECIFICATIONS, DESIGNS AND PRINCIPLES OF SIGNALING PRACTICE

W. M. Post, Chairman, Subcommittee; G. H. Dryden, W. J. Eck, J. C. Mock, C. A. Taylor, C. H. Tillett.

Current Activities of the Signal Section, A.A.R. Since November 1937

There are now available 21 of a series of 24 pamphlets on American Railway Signaling Principles and Practices prepared for the education of signal men and others desiring to study this subject.

The work performed during the 1937 fiscal year and reported at the 1938 Annual Meeting covers the following subjects:

1. Costs involved in stopping trains.
2. Centralized traffic control on the Missouri Pacific Railroad.
3. Automatic train control changed to automatic cab signals.

Bulletin 407, December, 1938.

4. Methods of protecting railroad crossing at grade where traffic conditions do not justify an interlocking plant.

5. Protection against lightning.

6. Protection against burnouts by lightning for lamps of highway grade crossing flashing-light signals.

7. Rectified a.c. track circuits.

8. Necessary modification of direct-current track circuits in detail or in principle to insure reliable protection of rail motor cars of passenger or freight-carrying type.

9. Development of proposed inductive co-ordination measures involving railroad power lines and power equipment, as a result of the adoption of the principles and practices for the inductive co-ordination of railway electric supply facilities and the communication facilities of the Bell System. (Co-operative Report)

10. Specification for centralized traffic control type neutral direct-current relay.

11. Corrective measures for phantom indication of light signals (other than highway crossing flashing light signals).

12. Definitions for technical terms used in signaling.

13. Instructions for fire protection for interlocking stations and other buildings housing signal equipment.

14. Signal performance reports.

15. Application of AAR unit table to C.T.C. installations.

16. Simplification of sizes and kinds of electric lamps for signal purposes.

17. Letter Symbols and Abbreviations—ASA Project Z10. (Co-operative Report)

18. Electrical insulating materials in general—ASA Project C–59. (Co-operative Report)

19. Requisites for automatic-gates highway crossings at grade over railway tracks.

20. Uniform timing of operation of highway-crossing protective devices by trains moving at various speeds over protected crossings.

21. Operation of highway-crossing protective devices at crossings where a train stops on the operating circuit and does not approach the crossing in a single continuous move.

22. Modifications of the National Electrical Safety Code to avoid conflict with recognized signal practice.

23. Stringing sags for weatherproof line wire.

24. Possible substitution of asbestos, varnished cambric or other types of non-inflammable materials as insulation for wire for use in signal stations.

25. Automatic train control and cab signals.

26. Increased speeds through automatic interlocking plants.

27. Use of automatic recorders.

28. Preferred height of light signals.

29. Use of low light signals in connection with automatic block signaling and interlocking including automatic interlocking.

30. Use of low light signals for movement against the current of traffic in multiple-track territory where track is signaled for both directions.

31. Noteworthy changes in signal practices.

32. Centralized traffic control installed on a complete subdivision on the Chicago, Burlington & Quincy, between Akron, Colo., and Denver.

33. Application of carrier currents.

34. An insight into eyesight.

Specifications Revised

	Old No.	New No.
Electro-Pneumatic Switch Operating Mechanism	152–36	152–38
Circuit Controller for Drawbridges	130–36	130–38
Electro-Mechanical Interlocking Machine	13433	134–38
Plug Type Rail Bonds and Track Circuit Connectors	15133	151–38
Track Circuit Rail Bonding	13530	135–38
Electrolyte	43–34	None
Signal Glasses	69–35	69–38
Kerosene Hand Lantern Globes	5927	59–38
Wrought Iron Bars	None	None

Drawings Revised

Single-Conductor Plug-Type Rail Bonds and Track Circuit Connectors	1631B	1631C
Duplex Conductor Plug-Type Rail Bonds and Track Circuit Connectors	1632B	1632C
Signal Masts (Details and Assembly)	1035A	1035B
One-Arm Mechanical Ground Signal	1043C	1043D
Two-Arm Mechanical Ground Signal	1044C	1044D
Anchor Post	1058A	1058B
Rocking Shaft Bearings	1061B	1061C
One-Way Pipe Carriers	1074A	1074B
Transverse Strap Pipe Carrier, Double Roller Type	1075A	1075B
Switch Circuit Controller Lug	1255B	1255C
Instrument Case, Style "A"	1626A	1626B
Instrument Case, Style "B"	1627A	1627B
Instrument Case, Style "C"	1628A	1628B

Requisites Revised

Mechanically Locking the Levers of Interlocking Machines. (Old title Mechanically Interlocking the Levers of Interlocking Machines.)

Minimizing Condensation and Frost Conditions. (Old titles Minimizing the Sweating of Relays and Minimizing the Sweating of Semaphore Signal Mechanisms.)

Instructions Revised

Installation and Maintenance of Copper-Oxide Caustic Soda Primary Cells. (Old title Installation and Handling of Caustic Soda Batteries.)

Table Revised

Signal and Interlocking Units.

New Specifications

	No.
Interlocking at Drawbridges for the Protection of Train Movements	175–38
Welded Type Rail Head Bonds and Track Circuit Connectors	178–38
Mechanically Applied Rail Head Type Bonds and Track Circuit Connectors	179–38
Bolts, Nuts and Threads	None
Electric Lamp Case	174–38
Weather-Resisting Braid Coverings for Aerial, Rubber-Insulated Wire and Cable	182–38

New Drawings

Welded Type Rail Head Bonds and Track Circuit Connectors	1047A
Mechanically Applied Rail Head Type Bonds and Track Circuit Connectors	1048A
Hand Lantern	1046A

Specifications Removed From the Manual

Lead-Type Portable Storage Battery for Signaling 8820
Battery Jar 11728

Drawing Removed From the Manual

Pinnacle 1050

Miscellaneous Matter Removed From the Manual

Automatic Train Control.
Clearance Diagram.

REPORT OF COMMITTEE 6—BUILDINGS

O. G. Wilbur, *Chairman;*
C. M. Angel,
G. A. Belden,
E. Christiansen,
H. M. Church,
A. C. Copland,
H. G. Dalton,
A. G. Dorland,
W. T. Dorrance,
E. A. Dougherty,
Hugo Filippi,
J. P. Gallagher,
W. E. Gardner,
J. N. Grim,
E. A. Harrison,
A. T. Hawk,
E. G. Hewson,
C. D. Horton,
N. D. Howard,
A. C. Irwin,
F. R. Judd,
L. P. Kimball,
L. H. Laffoley, *Vice-Chairman;*
H. C. Lorenz,
E. K. Mentzer,
H. A. Pasman,
G. A. Rodman,
C. H. Sandberg,
E. W. Scripture, Jr.,
L. W. Smith,
A. L. Sparks,
A. B. Stone,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A). Recommended changes in several Manual subjects are offered for adoption. Progress is reported in the work of revising the specifications for steel for railway buildings.

2. Preparation of specifications for railway buildings. No report.

3. Requirements and design of garage buildings for railway service. No report.

4. Maintenance of wearing surfaces of platforms and floors in railway buildings (Appendix B). Complete and offered as information.

5. Air-conditioning of buildings (Appendix C, Sections 1 and 2)

(a) For use by passengers and employees.

(b) For storage and treatment of fruit and produce.

Complete and offered as information.

6. Drinking water facilities in railway buildings, collaborating with Committee 13—Water Service, Fire Protection and Sanitation. No report.

7. Study of improved wearing surface for platforms (Appendix D).

(a) For heavy pedestrian traffic.

(b) For heavy traffic freight transfer platforms.

Complete and offered for inclusion in the Manual.

8. Railroad test laboratory—layout and test equipment (Appendix E). Complete and offered as information.

9. Drop pits—jacks and tables. No report.

The Committee on Buildings,
O. G. Wilbur, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

G. A. Belden, Chairman, Subcommittee; W. T. Dorrance, F. R. Judd, C. H. Sandberg.

SPECIFICATIONS FOR BUILDINGS FOR RAILWAY PURPOSES

I

GENERAL CONDITIONS

Revise Paragraph 114 to read as follows:

114. Force Account Work

Whenever any work is done or material furnished on a force account basis, that is, for a price based upon the actual cost and an added percentage, the percentage shall

include profit, overhead, general supervision, all taxes on profits, such as income taxes, also any Contractor's license fees and the use of all tools and equipment, except as noted in the definition of cost. The actual cost shall include all material, labor, small tools actually used up in the work, also compensation, public liability and contingent insurance, unemployment and old age insurance and sales or other taxes on items entering into the work, also the agreed rental of special power equipment. Where work is done on this basis, the time of all employees shall be entered by the Contractor on forms supplied for that purpose and checked and signed in duplicate daily by the Contractor and the Engineer and only time so entered and checked will be allowed.

Introduce the following paragraphs under the heading "IV CONCRETE" in Manual, page 6–10.

IV

CONCRETE

401. General

The Contractor shall furnish all labor, materials, tools, and equipment necessary to entirely complete the work herein specified and as shown or implied by the accompanying drawings and specifications.

402. Design and Installation

Concrete masonry shall be designed and installed in accordance with the "Specifications for Portland Cement Concrete, Plain and Reinforced" as published in the AREA Manual, Chapter 8, Masonry.

403. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed.

The General Conditions as given in Section I of this specification shall be considered to apply with equal force to this section of the specification.

X

1004. BUILT-UP ROOFING

MATERIALS

Revise the last paragraph on the bottom of page 6–30 to read as follows:

Slag shall be crushed from hard blast furnace slag and shall be dry and free from sand, clay or other foreign substances and shall range in size from ¼ inch to ⅝ inch.

XI

SHEET METAL WORK

Revise the following paragraphs as indicated:

1102. Materials

Sheet metal work shall be copper, galvanized iron or lead, as shown on the drawings, or as specifically called for in the contract.

Copper.—Copper sheets shall be rolled from copper conforming to the current specifications of the ASTM Serial designation B–4, and shall be marked with the weight and

manufacturer's name. Where lead coated copper is noted on the drawings, the copper shall have a total weight of coating of 15 pounds of lead per 100 square feet.

Copper flashings, valleys, eaves strips and roof pans shall be 16-ounce soft rolled copper.

Copper rain conductors, eaves troughs, moulded and hanging gutters and conductor heads shall be 16-ounce cold drawn or hard copper.

Copper cornices shall be not less than 16-ounce cold rolled or hard copper.

Galvanized Iron: No change.

Lead: Lead used for sheet metal work shall be not less than 4-pound rolled sheet lead.

1104. Flashings

Counter Flashings.—Revise the second paragraph under this heading to read as follows:

At masonry walls the counter flashing shall extend at least 2 inches into the horizontal joints of the masonry, or to the full depths of recesses in flashing blocks or other flashing units. Where no flashing block or other unit is called for on the plans, a reglet at least 2 inches deep shall be provided to receive the counter flashing. The sheets shall be bent to the required shape and set to fit closely over the base flashing, and the reglet filled with elastic roofing cement and the joint neatly flushed and pointed.

Insert a new paragraph reading as follows:

Through Wall Flashing.—Where called for on the plans, a through metal flashing shall be provided and built into the walls in accordance with the details. This flashing shall extend from the back of the wall to the outside face, and shall have a surface that will provide an adequate bond with the masonry. Transverse joints shall be locked or lapped at least 3 inches.

1112. Skylights

Where shown on the drawings, skylights of the sizes indicated and of approved design and manufacture, shall be set over curbs at least 10 inches above the roof. All sheet metal shall be reinforced for strength and stiffness with steel sections.

No change in second paragraph.

Skylights shall be designed to safely support a live load of 40 pounds per square foot in addition to the dead load, without deflection. Detail drawings for skylights shall be submitted for approval before the work is started.

XIII

CARPENTRY AND MILL WORK

Revise the following paragraphs, as indicated, and add new paragraph 1307a.

1301. General

Under the heading of "Carpentry and Millwork" shall be included all woodwork of every description, except lath, which forms a part of the completed building. Unless otherwise noted, sizes called for in specifications or drawings shall be nominal sizes conforming to American Lumber Standards (AREA Manual, Chapter 7.) The sizes of

all timber and lumber shall conform to the sizes shown on the drawings or specified hereinafter, and where sizes are not so indicated the Contractor shall request the Engineer to furnish this information before beginning the work affected. All lumber throughout the work shall be graded and classified in accordance with "Grading Rules and Classification of Timber and Lumber for Railway Uses." (AREA Manual, Chapter 7,) and shall be subject to inspection as received at the site. Rejected lumber shall be promptly removed from site by the Contractor.

1304. Dressing

Unless otherwise shown on the drawings, all lumber used throughout the work shall be surfaced on 4 sides to uniform widths and thicknesses, conforming to the finished sizes of American Lumber Standards, (AREA Manual, Chapter 7,) except that sills may be rough and platform joists need be dressed on 2 edges only.

1305. Treated Lumber

Where called for on the drawings, lumber treated with a preservative shall be used and such lumber shall be termed "Treated Lumber." Unless otherwise provided in this specification, the Railway Company will furnish all treated lumber, delivered on cars at the nearest available track to the building, and the Contractor shall provide for unloading, framing and erecting such lumber in his proposal, quality of workmanship to be the same as for other carpentry work under this specification. The Contractor shall furnish and apply 2 brush coats of approved preservative to all parts of the lumber that have been framed after treatment. The preservative material shall be heated before application if directed by the Engineer.

1307. Joists

Joists shall be of the dimensions shown on the drawings, and spaced as indicated. Through partitions carried from the ground floor up shall have a joist run close up against the same on either side at each floor. Joists carrying partitions, all trimmer joists, and all joists around wells or openings shall be doubled unless otherwise shown. Where their span is greater than 8 feet, joists shall be stiffened with bridging of the size shown crossed both ways between each joist, and placed at least every 6 feet. Ceiling joists shall be firmly spiked to the rafters.

(New paragraph)

1307a. Partitions

The top plates of all bearing partitions shall be doubled. The studs of bearing partitions running perpendicular to the line of joists shall extend through the floor to the girder below, or to the top plates of the supporting partition. The studs of partitions running parallel to the line of joists, shall be framed over double joists as described under "Joists" (1307), except that the studs of upper-story bearing partitions, if not continuous from the lower story, shall extend through the floor to the top plates of partitions below. Where non-bearing partitions run parallel to ceiling joists, a lathing member wide enough to provide nailing surface for ceiling lath shall be placed above the partition plates.

1309. Sheathing and Siding

Storm sheathing, when called for by the drawings, shall be nailed diagonally or horizontally as detailed, and nailed twice at every bearing. Horizontal sheathed walls shall be braced with a one-inch by four-inch diagonal brace (preferably 45 deg.) cut into the studs at each corner and each story. Where diagonal sheathing is used, the boards shall be applied at approximately 45 deg. and the direction of the sheathing shall be changed on each side, adjoining at a corner. Sheathing boards shall be of uniform width. Drop siding, shiplap and weather boards shall be placed truly horizontal with tight square butt joints, closely and accurately fitted against all casings, sills, water table and corner boards. All siding shall be drawn tight, secret nailed if called for, and when complete shall be windproof and rainproof.

1310. Flooring

Rough flooring shall be of the dimensions shown on the drawings (tongued and grooved if called for), evenly laid, in long lengths and securely nailed throughout, all joints to come on joists, except where end-matched sub-flooring is used. Finish flooring shall be kiln dried, dressed and matched, and of the dimensions shown on the drawings, with not more than two joints together, and shall be secret nailed with wire or cut floor nails as directed by the Engineer. It shall be smoothed by hand or machine to the final finish. No floor boards, unless end matched, except in closets, shall be less than 4 feet in length. Finish floors shall not be laid until the plastering is finished. Where maple flooring is called for as the finish flooring in warehouses and shops, it shall be of the dimensions shown and shall be square edged and end matched, and, unless otherwise directed, shall be face nailed with wire floor nails.

Flooring shall be tightly driven up before nailing so that joints are absolutely tight. Where wood floors are laid over concrete subfloors, a coat of approved liquid waterproofing compound shall be mopped over the concrete filling and screeds before the rough flooring is laid.

1318. Cabinets, Counters, Etc.

All cabinets, counters, drawers, lockers, shelving, etc., called for on the drawings, shall be provided in place and fitted up with all hardware as specified under that heading. All lumber for this work shall be kiln dried, and of the species and quality specified. Cabinet work shall be done in an approved manner, securely nailed and glued, and all drawers and cabinet doors shall work easily and fit accurately. Tops of counters shall be accurately joined, hand dressed, scraped and sandpapered so that joints will not show. Shelving shall be securely and rigidly built in place, supported by necessary brackets and cleats.

1319. Toilet Partitions

Where wood water closet partitions are called for on the drawings, they shall be provided with approved metal fittings and hardware, and doors in accordance with the details. In general, these partitions shall begin at a point 6 inches above the floor and extend to a point 6 feet above the floor.

1320. Sash

Sash shall be accurately made to fill openings, dressed and sanded to a smooth finish, pinned and through tenoned with muntins, etc., as detailed. They shall be rabetted for glass and moulded and shall be properly hung, hinged or pivoted as required. Sash shall be so made and installed as to provide for a watertight fit. Double-hung windows shall have the sash carefully balanced and counterweighted with cast iron or lead weights hung on approved sash cord or sash chains of proper strength. Sash shall be fitted to operate easily, but shall not be so loose as to rattle. Casement windows shall be made watertight by grooving the bottom rails and providing rebates at jambs, head and meeting stiles. Glass sizes, thicknesses, widths of rails and stiles will be as shown on the drawings. Where glass sizes only are given, width of rails, stiles and muntins shall be in accordance with standard mill practice.

All glass and glazing shall conform to Section XVI, Painting and Glazing, Articles 1624 and 1625.

1321. Doors (Second Paragraph)

Fire doors shall be built in accordance with AREA specification for "Fire Doors."

(Third Paragraph)

A special schedule of hinged doors, showing thicknesses, sizes, design, panelling, glazing, etc., will be furnished to supplement this specification where needed. In general, all panelled doors shall be 1¾ inches thick, except interior doors in minor buildings, which may be 1⅜ inches thick. Stiles and rails shall be mortised, tenoned, and pinned and doweled. In either case, joints shall be solidly glued up. Doors shall be hung with the proper size and number of butts to prevent sagging. Double-acting doors and gates shall swing clear and fill openings. Hardwood carpet strips or thresholds shall be provided for all doors, unless otherwise shown on the drawings.

1322. Shingles

Where called for on the drawings, roofs and exterior walls of buildings shall be covered with shingles of No. 1 Grade in accordance with AREA Specifications For Wood Shingles, the species and grade herein specified. They shall be laid 5 inches to the weather and nailed with, not to exceed two, 3d non-corrodible nails per shingle; ¼ inch shall be left between adjacent shingles for expansion. No split shingles or pieces shall be used. Shingles shall be laid in course which are truly horizontal or parallel with eaves, all joints truly vertical or perpendicular to eaves. Shingles shall be laid so that the joints will be at least 1½ inches apart in adjacent courses, and so that joints in alternate courses will not "line up." Shingles at eaves and base shall be started with double course projecting 1 inch below sheathing. Valleys shall have shingles cut parallel to valleys, leaving flashing exposed not less than 4 inches; the flashing shall extend not less than 10 inches on each side of the valley. Hips shall have shingles worked into Boston hips unless otherwise provided. All necessary saddle boards or ridge caps shall be provided and when completed, shingle roofs shall be watertight.

XVI

PAINTING AND GLAZING

In paragraphs Nos. 1602 and 1607 on pages 6–87, omit the word "raw", appearing three times.

Revise first paragraph of Section 1608 to read as follows:

1608. Painting Exterior Wood Surfaces

Exterior wood surfaces of every description, unless otherwise noted, shall receive, in addition to the priming coat, 2 coats of lead and oil paint or other approved formula of a brand and color satisfactory to the Engineer. The third coat shall consist of the ready mixed paint, applied as it comes from the container and used without thinning.

In Section 1609 revise sub-heading (a) to read as follows:

(a) Painting with 3 coats of lead and oil paint or other approved formula.

In Section 1610 add the words "or other approved formula" after "lead and oil paint."

In Section 1621 add the words, "or other approved" after the word "creosote."

XIX

1901— (a) HOT WATER HEATING SYSTEM, TWO PIPE GRAVITY,
(b) STEAM HEATING SYSTEM, ONE PIPE GRAVITY,
(c) STEAM HEATING SYSTEM, TWO PIPE GRAVITY.

The following changes are recommended:

5a. Boiler (Water)

Sixth paragraph. The word "Syphon" should read "Sylphon."

5b. Boiler (Steam)

Third paragraph. A comma should be placed between the words "syphon" and "safety valve."

Fourth paragraph. The word "Syphon" should read "Sylphon."

7b. Piping System (Steam)

Insert the following as a continuation of Article 7b ending on page 6–100:

The boiler shall be provided with a "Hartford" safety connection, which includes an equalizing pipe between the supply main and the return and the proper connection between the return line and the equalizing pipe. No valves are to be installed between the equalizing pipe or the return pipe and the "Hartford" safety connection.

13a. Valves on Radiator (Water)

Portion of last paragraph reading "on flow and return" should be stricken out, because it conflicts with the first paragraph of Article 13a.

16. Material to be used. (Water or Steam)

Sixth paragraph. Dimension "three inches" should be changed to "four inches."

17. Plastic Covering (Water or Steam)

Following paragraph should be inserted between paragraphs 1 and 2:

Boilers provided with insulating jackets by the manufacturers will be acceptable on this work.

24. Welding Pipe (Water or Steam)

Add new article reading as follows:

If wrought iron or steel pipe is used in connection with the installation of heating equipment, the contractor, if he so elects, may weld the pipe instead of using fittings. The welding shall be done in an approved manner in accordance with good engineering practice. The ends of pipes to be welded shall be properly chamfered. The welding when completed shall have no obstructions on the inside of the pipe and it shall be tested in accordance with the requirements of this specification. Should any leaks appear within the system, the contractor shall be required to make necessary repairs. Contractor shall specifically state in his proposal what method of assembling piping he will use.

25. General Conditions (Water or Steam)

No change, except in Article number.

XX

ELECTRIC LIGHT WIRING

2001. General

No change.

2002. Local Laws and Regulations

All electrical work shall be done in accordance with the National Electrical Code, except where local laws or regulations conflict, in which case such laws shall govern.

2003. Scope of Specifications

No change.

2004. Materials

The Contractor shall submit with his proposal the manufacturer's name, type and catalogue and identification numbers of all electrical devices and materials to be used, also complete wiring diagrams in triplicate showing the size of all wires and grades of covering. Devices and materials of equal grade may be substituted on approval of the Engineer but no material or appliance not approved by the National Electrical Code will be accepted.

2005. Conduits

Paragraph 1—

Wiring shall be installed in approved rigid or flexible conduit, or electrical metallic tubing, which shall be properly secured in place. Conduit shall be cut with a hacksaw and the ends thoroughly reamed. Conduits shall be free of sharp bends and of sufficient size to allow wires to be drawn without undue strain. During construction, ends of conduits shall be plugged at all outlets to keep the conduit dry and free of foreign substances.

Paragraph 2—No change.

Paragraph 3—No change.

Paragraph 4—No change.

2006. Wires

Paragraph 1—No change.

Paragraph 2—

Wire of No. 6 size A.W.G. and larger shall be stranded and may be either single or double braid, according to local requirements. No. 8 size wire may be either solid or stranded.

Paragraph 3—No change.

2007. Joints

No change.

2008. Outlet Boxes

No change.

2009. Service Switches and Cabinets

Service switches shall be essentially of the Safety First type installed separately and easily accessible.

Circuit cabinets shall provide for one more circuit than indicated on the drawings. When a lock is required it shall be of the cylinder type and provided with three keys.

2010. Local Switches

The local switches shall be of not less than 10 amperes capacity and shall be of the style and type indicated or directed. Where two or more switches come together, they are to be set in a gang box with one cover plate, unless otherwise provided.

2011. Fuses

Main and feeder circuits shall be provided with circuit breakers or fuses of the enclosed type which shall plainly indicate the amperes and volts for which they are rated. Branch lighting circuits shall be provided with ..... screw plug cutouts, and where lights are to be controlled from cabinet, approved detachable push or toggle switches, with insulated dead front covering, or equal, shall be installed.

2012. Wiring Systems

Unless otherwise specified, wiring for lighting shall be a multiple wire system of 110 to 220 volts. Feeders and branch feeders shall consist of three wires, and the neutral wire shall in all cases have the same current carrying capacity as the outside wires. Branch circuits shall be two-wire. No branch circuit shall carry more than 1,320 watts, except where especially approved.

2013. Outside Work

No change.

2014. Outside Wiring

Paragraph 1—Omitted.

Paragraph 2—

The Contractor shall furnish necessary meter loops of suitable fused safety service switches as hereinbefore specified, and extend the service wires through the exterior walls of the building for ready connection with the service company's supply wires.

Paragraph 3—

Wire supported on the exterior of walls or buildings shall be carried on racks or brackets not more than 10 feet apart, and parallel wires shall be spaced not less than 6 inches apart.

Paragraph 4—

Any wiring outside the building, either underground or overhead, that is to be installed by the Contractor shall conform to the requirements of the Association of American Railroads for line construction.

2015. General Conditions and Guarantee

No change.

Appendix B

(4) MAINTENANCE OF WEARING SURFACES OF PLATFORMS AND FLOORS IN RAILWAY BUILDINGS

H. M. Church, Chairman, Subcommittee; E. A. Dougherty, J. N. Grim, E. G. Hewson, C. D. Horton, G. A. Rodman, Dr. Edward W. Scripture, Jr., A. L. Sparks.

1. General

The maintenance of the wearing surfaces of platforms and floors in railway buildings requires consideration of methods and materials that will give the best wearing surface at the lowest annual cost. Types of maintenance can generally be classified either as patch repairs or resurfacing. The methods and materials selected will vary depending on whether the surfaces are for light or heavy-duty service. The platform and floor materials considered are wood, concrete, brick and bituminous.

2. Wood

Patch repairing is generally done with the same species of wood as originally used, particularly in the case of light-duty surfaces in passenger stations and similar buildings, where appearance is a consideration. In some instances, the service life of a wood floor may be extended by the application of a sanded bituminous coating on the worn wearing surfaces.

Unless the trucking lanes on wood floors or platforms are badly worn, they may be continued in service by laying steel plates on them. These plates should not be less than ½ in. thick and, before laying them, the floor should be made fairly smooth by dressing or filling the depressions with a sanded bituminous mixture.

Where a plank is not worn enough to impair its strength seriously, it may be reversed so as to place the smooth bottom surface on top.

Complete resurfacing of a wood wearing surface may be done with the original kind of wood or a more durable one. A different material may be used, depending on the duty required and the condition of the subfloor. See AREA Manual, page 6–209—Floors for Railway Buildings.

If a more durable species of wood is not available, one containing a large proportion of sapwood may be used if it is pressure-treated with a creosote or salt solution preservative and given a surface treatment after being in service long enough to give sufficient wear to insure bond. Preservative salt treatment of wood retards mechanical wear and if hard maple or similar species is not economically obtainable, soft maple treated with salt solution will give wear comparable with untreated hard maple.

Black gum with moderately-heavy to heavy interlocked grain does not easily split and has toughness to resist wear. The sapwood and heartwood are easily penetrated with a preservative. It is preferable to air-season it before dressing to finished size and it should again be air-seasoned after treatment. The ratio of thickness to the width of planks should be preferably, one to two.

Laminated wood flooring, with the narrow edge-grain face, gives a maximum abrasive resistance. It permits variable lengths of material and various methods of assembly, thus reducing cost. By alternating different widths the laminated flooring can be surfaced more effectively with bituminous mastic or concrete, when softwoods are used.

Platforms and trucking crossings of laminated construction at track level provide easier access to the track for maintenance, when they are assembled in removable slab units, and are less expensive than when flat plank construction is used.

Wood block floors are easily repaired by patching or complete resurfacing if necessary. Bituminous filler can readily be removed from old blocks by heating. If a sand cushion was used for the original construction, it should be replaced with bituminous sand or cement and sand. If the surface has unusual wear, it may be maintained reasonably smooth by bituminous treatment to prolong the life until complete resurfacing is economical.

3. Concrete

Concrete surfaces may be patched successfully if attention and care are given to proper preparation of the old concrete. It should be cut with vertical edges or preferably undercut. The surface of the old concrete should be thoroughly roughened and cleaned, and the thickness of the new surfacing should be not less than one inch. Just before placing new concrete the old concrete should be saturated with water and a cement grout coat brushed into the surface. Concrete or mortar for resurfacing should be mixed as dry as it can be handled, avoiding the use of excess water. The use of metallic aggregate with certain chemical admixtures increases bond, reduces shrinkage, and by increasing the density of the concrete reduces dusting and affords more effective resistance to mechanical wear. Small areas may be chipped out and patched successfully if the foregoing precautions are observed.

Thin renewals of concrete top surfaces of original two-course construction should be reinforced with wire mesh or expanded metal lath. The use of armoured concrete with small areas of metal exposed at the surface adds strength and resistance to abrasion.

Surface renewals in kind, of original monolithic construction can be made where raising of the surface level is not objectionable, or where the surface of the old concrete may be cut out to a depth of not less than one inch. Resurfacing should follow the same procedure as for original two-course construction.

Bituminous products are suitable for patch repairs of concrete floors. They are of several general types, such as emulsified asphalt with or without cement and bituminous cut-backs, and of various grades, requiring hot application. A bituminous primer should be used to insure bond. Such methods of patch repairing should be considered only where appearance is secondary.

An examination should be made of the design, material and workmanship in the original construction to ascertain the causes of deterioration. The cost of patch repairs should be compared with the cost of complete resurfacing, particularly if expansion was not adequately provided in the original construction. It is possible that the annual cost of complete replacement, according to standard AREA specifications, may be lower. See AREA Specifications for Buildings for Railway Purposes, Section XXII—Concrete Pavements and Foundations—page 6–122 of the Manual.

4. Brick

When patching or replacing brick floors, consideration should be given to the foundations and to the use of brick meeting AREA specifications. See AREA Specifications for Buildings for Railway Purposes, Section XXI—Brick Pavements and Floors—Page 6–116 of the Manual.

If repair of brick platforms requires the replacement of brick in excess of ten per cent of the surface, new brick should be used. Use good second hand brick for minor patch repairs. The original sand cushion should be replaced with a bituminous cushion, or a cement-sand base.

Brick platforms or floors may be repaired in kind or they may be covered with resurfacing material when worn. Various types of material are available for this purpost, such as specially prepared aggregates with cement and chemicals in combination with bitumastic material, either premixed or mixed in place. Such products generally have detailed manufacturers' specifications.

5. Bituminous

Bituminous mastic and prefabricated blocks, plank and comparable proprietary materials may be repaired in kind following manufacturers' directions. The materials and construction should meet the requirements of AREA Specifications for Buildings for Railroad Purposes. See appropriate sections in the Manual. Care should be exercised to maintain a uniform wearing surface.

This report is complete and is offered as information.

Appendix C—Section 1

(5) AIR-CONDITIONING OF BUILDINGS

(a) For Use by Passengers and Employees

A. C. Irwin, Chairman, Subcommittee; E. A. Dougherty, W. E. Gardner, E. A. Harrison, F. R. Judd, L. H. Laffoley, L. W. Smith.

Air-conditioning involves more than temperature control. The comfort of individuals is affected to a marked degree by the moisture content in the air for any given temperature; therefore any complete system must provide for humidity control.

"Effective temperature", that is, "temperature" as it affects the comfort of human beings is a function of both temperature and humidity. Thus, a relatively high temperature and low humidity is as effective in contributing to comfort or discomfort as a much lower temperature with higher humidity.

Dehumidification in the summer may be obtained by passing the air over cooled coil surfaces causing condensation, or by washers and absorption apparatus. Humidification in winter time is accomplished by spray nozzles, washers or humidifier pans.

In addition, cleansing and control of odors, drafts, etc., are a part of air-conditioning.

Local Building Regulations

Air-conditioning within urban centers will be subject to building code regulations, and the system used may be practically determined by arbitrary restrictions or provisions in the code. Certain systems may be impracticable because of the cost of meeting regulations of various kinds both codified and special. A first step therefore, in considering whether to install air-conditioning in a railroad building, is to ascertain what building

restrictions must be met, and whether the cost of so doing is prohibitive. The preliminary investigation should include water supply, sewer capacity, power and available space, both with respect to code and other regulations as well as practicability.

Water is the most common medium for taking heat away from a cooling system, either directly or from condensers. The quantity of water required is considerable, even for relatively small buildings, and the growth of air-conditioning has, in some instances, imposed a limitation on the amount of water used. It may be found necessary to install a cooling tower, but the expense and space required for such an installation should be compared with the cost of an adequate supply of water. Similarly, the discharge of air-conditioning water into storm sewers has had to be limited, in some cases, because of the added burden on capacity, which in times of heavy rain would overtax the capacity of the sewers.

Electric power is almost universally used for air-conditioning. The power supply should, therefore, be investigated both as to adequacy and availability at the point where it is needed. Where the system comprises a large number of units, distribution of power to these units may call for costly installations, especially when governed by strict codes. The size of existing wiring circuits should be investigated.

Where the refrigerant may come into contact with people by escaping into the air, it should be reasonably non-toxic, non-flammable and non-explosive.

Types of Installations

In considering the adoption of a central plant as against individual units, an analysis from the standpoints of economy and desirability should embrace relative noise, air velocity as it affects the occupants directly, humidity control, circulation, power distribution, disposal of cooling water through drains and connections, and suitability of available electrical current used by the equipment. The rated capacity of individual units should be compared with the spaces to be conditioned in order to insure that the units will not be overloaded, in which case the installation would be a failure; or underloaded, in which case the installation would be unbalanced and uneconomical. Space at windows for individual units is desirable, but may be occupied or required for other purposes.

A central plant may require an entirely new space or a costly re-arrangement of existing apparatus. A comparison of various systems should, of course, include water supply and disposal, and should include the possibility of a private supply, as from a well. A well has the advantage of low and nearly constant cooling temperature—a very important consideration in warm climates.

The economic set-up should include an investigation of the possibility for economy in the number, arrangement and size of units in the central plant. Thus, selection of sizes of compressors for flexibility may permit savings by shutting down certain units serving space that is occupied intermittently. In this manner, wear and tear is saved by operating only the compressors that are required at any given time.

While refrigeration equipment is usually employed in installations of considerable size, there may be locations where water at low temperature or ice at low cost would compare favorably with refrigerating machines. Also, there are locations where steam jet type equipment may be economical, as in a location where steam is generated at low cost and in large quantities. Where cool air is available from tunnels an unusually economical installation may be possible. Absorption systems that solve the water supply problem are also worthy of consideration. In other words, a "conclusion" should not be accepted unless it checks with known facts and a knowledge of requirements.

Space to Be Air-Conditioned

Spaces with high ceilings are easier to condition than those with low ceilings because if cool air is discharged into the space at a considerable height above the heads of people, it is safe to use incoming air at low temperatures at the grill outlet so that as the cool air settles into the breathing zone it will have absorbed heat and be so diffused that no effect of a "cold draft" will be felt. Air should "flow" and not "blow". As the height of discharge above the breathing zone decreases and the elevation of inlets approaches that zone, the temperature of incoming air must more nearly approach that set for immediate contact with occupants and must be in larger corresponding volume at reduced velocity.

Calculations for Capacity

Calculations for equipment are distinctly the province of the "air-conditioning" engineer, and should be based on a thorough survey of the property to be improved.

Appendix C—Section 2

(5) AIR-CONDITIONING OF BUILDINGS

(b) For Storage and Treatment of Fruit and Produce

F. R. Judd, Chairman, Subcommittee; E. A. Dougherty, W. E. Gardner, E. A. Harrison, A. C. Irwin, L. H. Laffoley, L. W. Smith.

This subject covers two distinct phases in the marketing of perishable products.

(1) Storage, during which time an attempt is made to arrest the natural ripening process of a product.

(2) The controlled ripening of a product to suit the market demand.

The first phase requires a cold storage plant in which the storing temperature is obtained by the use of mechanical refrigeration and the necessary equipment for air circulation or ventilation, with required humidity.

The results of the second phase depend a great deal upon the care given the products during the first phase; for instance, the following is quoted from the 1936 Export Manual of the Oregon–Washington Pear Bureau:

> "Bosc pears should be held constantly at 30 to 31 deg. F. and after cold storage, they must be ripened at temperatures between 60 and 70 deg. F. They will not ripen in cold storage and they lose their ability to ripen if held for any length of time at temperatures between 34 and 55 deg. F. If held at these temperatures for any length of time, they soon reach a stage where they scald and break down when attempts are made to ripen them."

COLD STORAGE

In order to provide the proper facilities for storage of any particular product, it is necessary to have a knowledge of the following factors:

For Storage

(1) Temperature range at which commodity can be successfully stored.

(2) Range of relative humidity.

(3) Necessity of ventilation.

(4) Necessity of air circulation, without ventilation.

(5) Quantity of commodity to be handled at one time.

For the cold storage of fruit and vegetables, it is highly important that the temperature of storage rooms be held fairly constant. Variations of two or three degrees above or below the desired range are in most cases too large.

Control of temperature is usually easier in large rooms than in small ones if both are filled to capacity. This is due to the latent effect produced by the larger mass of material, both commodity and building material. Refrigeration is thus stored up and temperature changes occur more slowly. For this reason, small storage rooms generally require closer attention than large ones. Small storage rooms, however, may be required, due to the variety of products to be stored, in order that they may be segregated; for instance, pears should be stored by themselves and should not come into contact with other products. Odors are readily absorbed by pears and may impair their flavor.

The relative humidity of the air in storage rooms has a direct relation to the keeping quality of the products held in them. If it is too low, wilting is likely to occur in most fruits and vegetables, especially of the leafy types; if it is too high, it favors the development of decay, especially if accompanied by a considerable variation in temperature.

For most fruits stored commercially, a relative humidity of 80 to 85 percent gives the best results. For leafy vegetables and root crops, the relative humidity should be about 90 to 95 percent and in general for other vegetables, from 85 to 90 percent.

In any consideration of the storage of fruits and vegetables, it should be realized that these commodities are alive and therefore carry on within themselves many of the processes characteristic of all living things. Unless the relative humidity is high, they give off moisture to the surrounding air and most of them in time become shriveled and wilted even at 32 deg. F.

It can be stated that for most fruits and vegetables, so far as is now known, cold storage is beneficial rather than harmful. Bananas are an exception, because if held at temperatures below 56 deg. F., they become chilled and then will not ripen properly in a ripening temperature.

The duration of time in which the majority of the fruits can be held in storage varies considerably; for instance, the citrous fruits, such as oranges, lemons, grapefruit, limes, etc., can be successfully stored for varied periods from a few weeks to four or five months, while berries, with the exception of cranberries, can only be held in storage for a very short period. Cranberries can be satisfactorily held for approximately three months. Then again, such fruits as cherries are not adaptable to storage at all, very seldom being held more than one or two days. Peaches are not adaptable to cold storage. However, if they are sound and well matured, but not overripe, they could possibly be held for a period not to exceed two weeks with little or no bad effect on the flavor, texture or appearance of the fruit.

The storage requirements for vegetables vary considerably. Some vegetables, such as the leafy variety, are very seldom held in storage, while other varieties, such as potatoes, onions, etc., can be held for considerable periods.

It can therefore readily be understood that in order to provide proper facilities for storage of any particular product, whether fruit or vegetable, it is necessary to have a definite knowledge of the particular product which is to be handled, the varieties being too numerous to formulate any definite rules to be followed in general.

RIPENING

The second phase "controlled ripening" requires a conditioning plant involving—

(1) Controlled humidity.
(2) Controlled air circulation.
(3) Controlled ripening temperature.
(4) Controlled ventilation.

The results of the second phase depend a great deal upon the care given the product during the first phase. In order to provide the proper facilities for the treatment of any particular product, it is necessary to have a knowledge of the following factors:

(1) Temperature range at which commodity must be maintained for ripening.
(2) Range of relative humidity.
(3) Necessity of ventilation.
(4) Necessity of air circulation, without ventilation.
(5) Total quantity of commodity to be held in ripening room at one time.
(6) Rate at which commodity will be moved in and out of ripening room.

When fruits or vegetables are removed from a low temperature to a higher one, condensation of moisture from the air takes place on the cool surface of the commodity. This is known as sweating and is more marked, the higher the relative humidity of the warmer air. This should be prevented if possible in the case of onions and the more tender fruits to reduce the tendency to decay. Sweating can best be reduced by allowing the commodity to warm up gradually. Constant circulation of the air of the ripening room will also reduce the sweating somewhat. Commodities of this nature require careful attention and handling and should be marketed for consumption without undue delay after the cold storage period.

Most fruits or vegetables are mature or ripe when harvested and require no special artificial ripening process or treatment and are only held, either in common or cold storage, for a limited time until they are placed on the markets for ultimate distribution to consumers. There are some exceptions, one being the banana, which is one of the fruits that must be shipped to market in a green condition, as the ripened product is soft in texture and cannot be well handled without serious injury. Another of the fruits that is harvested in a semi-ripe state is the pear. Both of these fruits require an artificial ripening process or treatment before they are ready for the consumers' market.

Apples are one of the fruits in which the natural process of maturing and ripening continues, even in cold storage. Of the vegetables, tomatoes are also in this class; therefore, while no special artificial ripening process or treatment is required for these products, care must be taken in handling them through storage to insure that they are put upon the consumers' market in ample time to prohibit decay or loss in quality before sale to the consumer.

It can readily be understood, therefore, that in order to provide proper facilities for either artificial ripening or treatment of any particular product, whether fruits or vegetables, it is necessary to have a definite knowledge of the particular product which is to be handled, the varieties being too great to formulate any definite rules to be followed in general.

Banana Ripening

The controlling factors in banana ripening are generally recognized to be temperature, humidity and ventilation.

Ripening Temperature

The most desirable temperature range for ripening lies between 62 and 68 deg. F. Little if any harm appears to result to hard green fruit from temperatures 5 to 10 deg. higher than 68 deg. F. for a period of a half day or so, if very high humidity is maintained. Temperatures above 66 deg. are not recommended for turning or ripe fruit. For fast ripening, experiments have demonstrated a decided advantage is obtained in raising the temperature quite rapidly, even as much as 3 deg. per hour, until the fruit

itself is warmed up to the desired ripening temperature. Heavy condensation of moisture on the fruit during the warming period appears to be beneficial and is an indication that ample moisture has been provided. For holding ripe fruit, temperatures not lower than about 56 deg. F. are recommended.

Humidity

Humidity is the second most important factor in ripening. High humidity is needed to prevent excessive shrinkage, especially at the warmest ripening temperatures. Where air velocity is rapid from forced air circulation, high humidity is especially important to avoid drying out of the fruit. After fruit has begun to color, if it must be held over in the ripening rooms, the very high humidity recommended for green fruit should be reduced moderately to avoid mould, tender fruit, etc. A relative humidity below 70 to 75 percent is not recommended even for ripe fruit on account of the excessive shrinkage which results.

Numerous careful tests have been made to determine the effect on shrinkage of different ripening room conditions. For example, tests made show an average shrinkage of 3.8 percent for a six-day ripening period in a room held constant at a temperature of 67 deg. F., with a relative humidity ranging from 75 to 80 percent. Fruit in another room, strictly comparable in every respect except that the relative humidity was kept at 90 to 95 percent, shrank 2 per cent during the same six-day period. Low humidity is sometimes the cause of delayed and irregular ripening. Transpiration is regulated by tiny microscopic openings in the peel, which are known as "stomates". These openings tend to close in a dry atmosphere and it is thought that in so doing they retard respiration and ripening changes.

Ventilation

Bananas during ripening give off carbon dioxide, an inert gas, and, in addition, small amounts of volatile esters. It has been fully demonstrated in practice that bananas ripen more readily and uniformly if the gases given off by the fruit are confined in the ripening rooms instead of being dissipated by ventilation.

Time Required for Ripening

Strictly within limits, the period required for ripening green bananas can be extended or shortened to meet the requirements for distribution at the most desirable stage of ripeness. Under average conditions, this period cannot be cut shorter than about three or four days, or extended beyond about eight or ten days without resort to drastic treatment liable to affect the quality and saleability of the fruit adversely. Ripening treatment can be controlled to accomplish fast ripening (three to four days average), medium ripening (five to seven days average) and slow ripening (nine to ten days average).

Use of Ethylene Gas

Under certain conditions, ethylene gas is used to produce uniformity in ripening and to speed up slow ripening fruit. The gas is an anesthetic, but the very diluted amount used for ripening does no harm to workmen. Ethylene gas as released from the drum is inflammable, therefore open flames must not be allowed in ripening rooms at the time it is being discharged from the drum. The mixture of ethylene gas and air is neither inflammable nor explosive, except at very much higher concentrations than those recommended for banana ripening.

Pear Ripening

To obtain the flavor and texture characteristic of late pears, it is often necessary that the fruit be ripened after cold storage. Some varieties do not ripen at all if kept constantly at cold storage temperatures. This is particularly true of Beurre Bosc, Howell and sometimes of Doyenne du Comice. Varieties such as Beurre d'Anjou, Winter Nelis and Beurre Easter will usually ripen at low temperatures if given ample time, but even in the case of these sorts, the quality is superior when warm temperatures are provided during the final stages of maturation. Late pears can be removed from cold storage and ripened at any time during the normal life of the variety. All late pears ripen well at temperatures between 60 to 70 deg. F.* Ripening rooms, such as are used for the ripening of bananas, are satisfactory for late pears. To obtain the best results, it is recommended that ripening rooms be maintained at 60 deg. F. and that humidity be provided, either by keeping the floors in a dampened condition or by the use of commercial humidifiers. Ripening rooms do not need ventilation. They function best when kept closed at all times.

In case regular ripening rooms are not available, the fruit can be ripened at ordinary living room temperatures. They usually ripen out-of-doors, provided the prevailing temperatures are around 60 deg. F. Failure to ripen properly is frequently experienced when late pears are merchandised during the cold months of the year and it is recommended that ripening facilities be provided during these months.

EQUIPMENT

The equipment required for the treatment of fruits and vegetables depends on the commodity to be handled. In order to provide facilities to take care of this class of work, it is first necessary to construct the room which will result in the most efficient and economical operation. This means that careful consideration has to be given the construction of the room, especially to the type of insulation provided. Where an old building is being used, the best type of insulation is that which is laid up, such as cork board, rock cork, etc. Loose insulation that is filled in between joists, rafters, etc., cannot be utilized with the same certainty, on account of the fact that it is difficult to fill inaccessible places. This type of insulation can, however, be used successfully in new buildings. The amount of insulation used is determined by the commodity to be handled and the geographical location of the plant. Care should be exercised in designing the openings to the insulated space. Properly insulated doors should be provided and if the occasion demands, ante-rooms should also be provided.

After the type of structure has been determined, care should be exercised in the mechanical equipment to be selected. A compressor of adequate size, determined from calculations based upon the best engineering practice and conditions under which the compressor is to operate, should be selected. If the plant is to operate automatically with comparatively little attention, the machine should operate at a slow speed. This will require a larger unit than would be required if a high-speed machine were selected, but owing to the fact that the former machine would be of more sturdy construction, it will be more reliable. The refrigerant to be used in the unit is an important factor and is also dependent on local conditions. If the refrigerating room is located so that adequate exits can be provided and the commodity being handled will permit, there is

* United States Department of Agriculture Bulletin No. 140—Investigation on the Handling of Bartlett Pears from Pacific Coast Districts—states the best ripening temperatures for Bartlett pears, either immediately after picking or following a period in cold storage, seems to be from 60 to 70 deg. F. Fruit ripened at temperatures below 60 or above 70 deg. was inferior to that ripened at 60 to 70 deg.

no objection to using a toxic refrigerant. However, if the exits are limited, it is advisable to use a non-toxic refrigerant.

The compressor should be installed in a location that is adjacent to the space to be refrigerated. It is assumed that the refrigerating plant to be provided is of such a size that it is necessary to utilize water for cooling. This naturally introduces a problem of securing the water and disposing of the water after it has served its purpose. In locations where the cost of water is comparatively low and the supply plentiful, and the amount of the used water will not cause any inconvenience, it is recommended that this procedure be followed. However, if conditions are opposite to the above, it is recommended that a cooling tower of adequate capacity be used.

If the conditioning equipment is used during the entire year and the geographical location of the plant requires heating during the winter, this feature should be taken care of. The refrigerating machine should be equipped with the necessary apparatus to provide economical and efficient operation, that is, it should be provided with apparatus that will protect it from damage due to various conditions that arise. The cooling units in the refrigerating room are also determined by the commodity to be handled. Some commodities require the use of coils, such as pipe, fin type, etc. Others will permit the use of unit coolers. The latter equipment is coming into more general use on account of the fact that the cooling surface required is less, due to the fact that the cooled air is circulated throughout the room by means of an electrically driven fan instead of by gravity, which is the case where coils are used. The use of unit coolers also lends itself more readily to automatic operation.

If the commodity to be handled requires humidification, provision must be made to take care of this condition by the most suitable means local conditions will permit. Humidification can be provided by either steam jet or water spray. In the case of large installations, both methods should be provided. Steam, when available, can be used during the heating season; if steam is not available, water will be required. During the non-heating season when there is no steam available, water is to be used. If heating is required for the treatment of fruits and vegetables, heat should be introduced into the storage rooms by the best means available.

The treatment of fruits and vegetables depends upon the application of certain principles developed, either scientifically or by experiment. If feasible, the use of automatic control apparatus can be used to eliminate guess work, thereby insuring uniform treatment.

Exhibit A

Exhibit A contains information collected from various sources concerning cold storage and ripening of various commodities. That on commodities comprising fruits, berries, melons, vegetables and flowers is taken from the classified railroad tariffs. While information on all of these commodities is not available at present, they have been listed with the idea of adding the information whenever it becomes available.

The meats, fish, beverages and dairy products are not divided into various classifications in the tariffs as are the other commodities, therefore the commodities listed under meats, fish, beverages and dairy products were taken from the various authorities on cold storage and consequently the data are much more complete.

This report is complete and is offered as information.

Exhibit A.—Physical Requirements for Cold Storage and Ripening of Various Perishable Products

Item	COLD STORAGE						RIPENING			
	Various Authorities			U. S. Dept. Agriculture			Various Authorities			
	Temperature Degrees	Humidity Percent	Air circulation	Temperature Degrees	Humidity Percent	Air circulation	Temperature Degrees	Humidity Percent	Air circulation	Time
FRUITS										
Alligator pears										1-2 months
Annona	31—34	75—80	Moderate	31—32	85—88		31—70			
Apples	35—40	80								
Apricots	35	85								
Avocados	56—72	70—90					56—70	90—95	3 or 4 changes per hour	8-10 days
Bananas										
Breadfruit										
Cactus fruit										
Calavos										
Carob										
Carshew										
Cherries	38—40	75		31—32	80—85		38			
Citrons (not melons)										
Cocoanuts										
Damsons										
Dates	40—50	75								
Figs		75								
Flavocados										
Granadillas										
Grapes	33—38			30—32	80—85		38			
Grapefruit	32—36			32	85—90					
Guavas										
Hovenia										
Jew plumes										
Jujubes										
Kaki										
Kumquats								80		
Lemons	36—41			50—55	80—85					
Limes										
Loquats										
Manderines										
Mango										
Marmalade plums										
Medlar										
Myrica										
Nectarines										
Olives								80		
Oranges	32—35	80		32	80—85					
Papaw										
Peaches	32—34	80		31—32	80—85					9-45 days
Pears	32—36	90		30—32	85—90		43—70			
Pears—Prickly										
Persimmons										
Pineapples	32—40	75								

Plantain						43—52		12 days
Plums	32—36	80		31—32	80—85			
Pomegranates								
Pomelos								
Prunes	33	80						
Quinces				31—32	80—85			
St. Johns Bread								
Sapodilla								
Shaddocks								
Tamarind								
Tangerines								
Dried Fruits				32—50	70—75			
Frozen Fruits				15—18				
Nuts				30—32	75—80			
BERRIES								
Blackberries	32—33			31—32	80—85		32—33	
Blueberries								
Cranberries	33—36	75		32—40	80—85			
Currants	38							
Cowberries								
Dewberries				31—32	80—85			
Elderberries								
Gooseberries	32—34							
Himalayaberries								
Huckleberries								
Juneberries								
Lingonberries								
Loganberries				31—32	80—85			
Mulberries								
Raspberries	32—33			31—32	80—85		32—33	
Strawberries	32—33	73		31—32	80—85		32—33	
Whortleberries								
Wineberries								
MELONS								
Cantaloupes	33—36	80		50—55	75—85			
Casaba Melons				50—55	75—85			
Christmas Melons								
Citron Melons								
Honey Dew Melons				50—55	75—85			
Mango Melons								
Musk Melons								
Osage Melons								
Persian Melons				50—55	75—85			
Water Melons	33—36			50—55	75—85			
VEGETABLES								
Artichokes	39	82		31—32	90—95			
Asparagus	33—36	80	Moderate	32	85—90			
Beans (Green)	33—36	75		32	85—90			
Beans (Lima)	33—35	70		32	85—90			
Beans (Dried)	36—45	70						

EXHIBIT A.—PHYSICAL REQUIREMENTS FOR COLD STORAGE AND RIPENING OF VARIOUS PERISHABLE PRODUCTS—Continued

Item	COLD STORAGE						RIPENING			
	Various Authorities			U. S. Dept. Agriculture			Various Authorities			
	Temperature Degrees	Humidity Percent	Air circulation	Temperature Degrees	Humidity Percent	Air circulation	Temperature Degrees	Humidity Percent	Air circulation	Time
VEGETABLES (Continued)										
Beets	32—40	70		32	85—95					
Berry Plants										
Broccoli	33—36	80		32	85—90					
Brussels Sprouts	33—36	80								
Cabbage	31—36	80	Moderate	32	90—95					
Cardoon										
Carrots	33—36	80		32	90—95					
Cassava										
Cauliflower	32—36	85		32	85—90					
Celeriac										
Celery	32—34	80		31—32	90—95					
Celery Cabbage										
Celery Lettuce										
Celery Root										
Chards										
Chicory										
Chives										
Collards										
Corn (Green)	36—38	80		31—32	85—90					
Corn (Dried)	45									
Cress										
Cucumbers	32—38	75		50—60	80—85					
Cymlings										
Dasheens (Malangas)										
Egg Plant	37	75		50—60	85—90					
Endive	35	80		32	90—95					
Escarole										
Eschallots										
Garlic				32	70—75					
Gherkins (Pickles)										
Greens										
Gumbo										
Hops										
Horse Radish				32	85—90					
Kale										
Kohl-rabi										
Leeks				32	85—90					
Lentils										
Lettuce	30—42	80		32	90—95					
Malangas (Dasheens)										
Mushrooms	32—34	80	Moderate							
Okra	33	80								
Onions	32—35	80	Strong	32	70—75					
Onion Sets				32	70—75					
Oyster Plant										

Parsley									
Parsnips	33—35	80		32	90—95				
Peanuts (Raw)									
Peas (Dried)	40								
Peas (Green)	32—35	80		32	85—90				
Pepper Grass									
Peppers (Green)	34	80		32	85—90				
Plants (Vegetable & Berry)									
Potatoes (White)	33—40	70	Moderate	36—50	85—90		45		
Potatoes (Sweet)	50—55	70		50—55	80—90		33—85		
Pumpkins	34	80		55—60	70—75				
Radishes	32—35	80		32	90—95				
Rhubarb	33	80		32	90—95				
Romaine									
Rutabagas				32	90—95				
Salsify				32	90—95				
Savoy									
Shallots									
Sorrel									
Spinach	33	80		32	90—95				
Sprouts									
Squash	33—36	80		55—60	70—75				
Tomatoes	35—40	70		50—70	80—85		60—77	85	10-19 days
Turnips	33	80		32	90—95				
Vegetable Oyster									
Vegetable Plants									
Yams									
Yucas									
Miscellaneous Vegetables	34—40	High							
FLOWERS	45—55								

EXHIBIT A.—PHYSICAL REQUIREMENTS FOR COLD STORAGE AND RIPENING OF VARIOUS PERISHABLE PRODUCTS—Continued

Item	COLD STORAGE Various Authorities Temperature Degrees	Humidity Percent	Air circulation
MEAT AND MEAT PRODUCTS			
Bacon, fresh	30—32	80	
Bacon, smoked	30—32	70	
Beef, frozen	10—20		
Beef, fresh fat	33—36	84	
Beef, fresh lean	33—36	85	
Beef, dried or salted	34	70	
Bologna	31—36	70	
Corned beef, pickled	32—36	82	
Chicken	28—30		
Frogs legs, frozen	18		
Game, storage	20—25		
Game, freezing	5—10		
Hams, fresh	32—34	80	
Hams, smoked	32—40	65	
Hams, pickled	32—40	82	
Hams, frozen	8		
Lamb	32—36	82	
Lamb, frozen	8		
Livers, fresh	32—34	83	
Livers, frozen	17—25		
Lard	32—38	80	
Mutton, fresh	32—36	82	
Mutton, frozen	8		
Minced meat	36—40		
Meats, miscellaneous, canned	40		
Pork, fresh	32—36	80	
Pork, dried and salted	32—38	85	
Pork shoulders, frozen	15—20		
Pork, frozen	8		
Pork bellies, frozen	8		
Poultry, dressed	28—30	70	
Poultry, frozen	0—10		
Pigeons	28—30		
Sausage, fresh	32—36	80	
Sausage, smoked	32—34	70	
Sausage casings	12		
Salami	32—34	70	
Tongue, pickled	32—36	82	
Veal, fresh	34—40	82	
Veal, frozen	8		
FISH AND FISH PRODUCTS			
Caviar	28—32	70—85	Moderate
Fish, dried	30—40	60—70	Moderate
Fish, fresh	25—28	75—85	Strong
Fish, fresh iced	25—29		
Fish, smoked	18—28	78—85	Strong
Fish, frozen	5—18	70	
Herrings, fresh	5—20	70—80	Strong
Herrings, red	25	70	
Herrings, salted	25—32	70	Moderate
Lobsters, alive	39	High	Moderate
Lobsters, boiled	25	90	
Oysters, in shell	30—35	High	Moderate
Oysters, opened	20—25	High	Moderate
Oysters, in liquid	20—25		
Salmon	25	80	
Salmon, glazed	14—21		
BEVERAGES, BEER AND WINES			
Beer, Pilsner on tap	Up to 43	90	Moderate
Beer, Munchner on tap	Up to 45	90	Moderate
Beer in barrels	43—47	90	Moderate
Cider	30—34		
Wine, Rhine and Moselle	43—50		
Wine, Bordeaux and Burgundy	Up to 57		
Wine, heavy	Up to 65		
Grape Juice	32—34	90	Moderate
DAIRY PRODUCTS			
Butter, short time storage	36—40	75—80	
Butter, long time storage	0—25	80—75	
Butter, grease			
Cheese, storage room for miscellaneous	41—46	75—85	

EXHIBIT A.—PHYSICAL REQUIREMENTS FOR COLD STORAGE AND RIPENING OF VARIOUS PERISHABLE PRODUCTS—Continued

Item	COLD STORAGE Various Authorities Temperature Degrees	Humidity Percent	Air circulation
DAIRY PRODUCTS—Continued			
Cheese, American	32—40		
Eggs in shell	31—33	75—95	Rapid while
Eggs, powdered or dried	32	60	cooling
Eggs, frozen in cans	0—10		
Ice cream			
Milk, fresh	32—36		
Milk, butter	32—40		
Milk, powdered	30		
Oleomargarine	20—30		Moderate

Appendix D

(7) STUDY OF IMPROVED WEARING SURFACE FOR PLATFORMS

(a) For heavy pedestrian traffic.

(b) For heavy traffic freight transfer platforms.

H. M. Church, Chairman, Subcommittee; E. A. Dougherty, J. N. Grim, A. T. Hawk, E. G. Hewson, C. D. Horton, E. K. Mentzer, G. A. Rodman.

PLATFORM SURFACES

Uses and types recommended to provide wearing surface

1. General

Uses and types of surfaces for platforms in railway service may be classified as follows:

(a) Passenger stations.
Wood, brick, concrete, bituminous premixed or mixed in place, special products.

(b) Shops and car yards.
Concrete, wood blocks, bituminous premixed or mixed in place.

(c) Piers, warehouses and freight houses.
Wood, concrete, wood blocks, bituminous premixed or mixed in place, asphalt mastic on concrete base, steel plates.

2. Wood

Wood is the most generally used material for surfacing railway platforms. If the wood is untreated the most durable species, consistent with cost, should be used. The cheaper non-durable woods containing a large proportion of sapwood, when pressure treated with creosote or salt solutions, give good service life. Sapwood can be more effectively treated and its strength, compared with heartwood, is not materially less.

For light traffic, soft woods with preservative treatment give satisfactory results. Black gum, treated, resists wear and is moderate in cost. Greenheart, a tropical wood, is suitable for heavy duty wearing surfaces because of its density and stiffness. Preservative treatment is not required as it has a long life.

As wood surfaces wear, asphalt emulsions mopped on and dusted with sand are durable when protected from the weather. This coating should not be applied to treated wood until bleeding or leaching has stopped.

3. Brick

Platforms with brick surface are extensively used and have many advantages. They are easily and economically repaired and the brick may be readily salvaged. For marking purposes, such as clearance lines, a light colored brick may be used in conjunction with the darker colors. The foundation should be carefully prepared and the brick selected of the type for the service required. See AREA Specifications for Buildings for Railway Purposes,—Brick Pavements and Floors, Section XXI, page 6–116 of the Manual.

The brick may also be laid on a well rolled and smooth base of cinders, gravel, crushed stone or slag.

In addition to asphalt, coal tar pitch may be used in the mastic cushion and as a filler. Asphalt and coal tar pitch are poured hot into the joints between bricks. Cement and sand filler may be used dry and wetted after placing or may be poured into the joints in the form of grout.

4. Concrete

Platforms with a concrete surface made of selected aggregates properly mixed and cured give good results under heavy service. Inattention to the requirements of making good concrete has been the cause of unsatisfactory results.

There are a number of special or patented concrete aggregates on the market giving surfaces which resist wear and the action of the elements. There are also many types of steel grids or grills which may be imbedded in the concrete to form an armoured surface against heavy duty. See AREA Specifications for Buildings for Railway Purposes—Concrete Pavements and Foundations, Section XXII, page 6–122 of the Manual.

The two methods of concrete platform construction are the one-course and the two-course. In one-course work the base and topping are poured in one operation as a uniform slab. In two-course work the base is poured and the topping or wearing surface placed before or after the concrete in the base has set.

The concrete should be thoroughly compacted but not enough to bring water or an excessive amount of mortar to the surface. If the water separates there is a tendency to form a top layer of concrete having a high water-cement ratio, resulting in a weak surface and greater shrinkage. Proper grading of aggregates and proportioning of the mix will reduce the tendency to separate. Not more than 20 percent of the total aggregate should be retained between two successive sieves of the standard set. At least 10 percent of the sand should pass No. 50 sieve to give sufficient fines. The volume of sand should be not less than one-third of the total volume of aggregates nor more than one-half the total, based on surface-dry materials. Allowance for bulking of the sand on account of moisture will increase these proportions.

One-course construction is usually finished with a gritty surface by hand floating. A vibrating screed is recommended as it permits a stiffer mixture and assures better compacting. Care must be taken not to vibrate to such an extent as to cause a thick layer of mortar to be brought to the surface. Cement, or a mixture of cement and sand, should not be added to the surface. If a smooth finish is desired it may be produced by troweling after floating.

Cement-bound macadam may be used in one-course work by spreading the aggregate in the desired thickness, rolling or tamping, and grouting with a cement-sand-water mixture and compacting. The surface should be finished with a gritty texture. See AREA Specifications for Buildings for Railway Purposes,—Cement, Grouted Macadam Platforms, Floors, Pavements and Pavement Foundations, Section XXVI, page 6–153 of the Manual.

Two-course construction is generally used for indoor floors where a smooth surface is desired. The base is poured in the same manner as one-course work. The topping should be composed of 1 part cement, 1 part sand and from 1½ to 2 parts of pea-size gravel or crushed stone, graded from ⅛ to ⅜ inches. This mixture requires less water, has less shrinkage and the coarser aggregate at the surface withstands the wear. Silica, granite and trap rock are most suitable for the coarse aggregate. Softer materials do not wear well. Sands containing stone-dust, clay or silt are particularly objectionable. If a topping of cement and sand mortar is used it is easily spread and finished, but will shrink and result in crazing, dusting and poor wearing qualities.

Coarse aggregate, to resist abrasion, shall meet the following requirements for loss of weight when tested in accordance with current ASTM Designation D–2, Standard method of test for abrasion of rock, and ASTM Designation D–298,—Tentative method of test for abrasion of gravel.

Material	*Maximum Loss Percent by Weight*
Crushed stone	5
Gravel, uncrushed	10
Gravel, 100 percent crushed	20

A mechanical float consisting of a motor operated rotating steel disc may be used for compacting. It permits the placing of a stiff mixture which is desired as it reduces the tendency for water to come to the surface.

If the topping is laid after the base has set, the surface of the base should be finished rough and wetted when ready to place the topping. No pools of water should be standing on the base when the topping is placed, and the surface should be covered with a neat cement grout mixed to the consistency of thick paint and thoroughly brushed in and spread.

A new concrete surface may be placed over an old concrete floor if it is thoroughly cleaned and saturated with water for several hours. The topping should be about two inches thick and reinforced with wire mesh weighing 30 pounds per 100 square feet. Joints in the new topping should coincide with joints in the old floor.

5. Bituminous

Wearing surfaces of bituminous materials are often used for platforms. The base course may be of cinders, crushed aggregates and mixed or penetrated concrete. The comparative cost is low.

The bituminous products may be natural asphalts, emulsified or cut-back asphalt or coal tar. Some types of emulsified asphalt may be mixed with Portland cement. The manufacturers' recommendations as to the methods of mixing should be followed to give the best results. Asphalt on mill-type or laminated wood floors gives a good wearing surface.

Where absolute water-tightness is essential or in situations subject to acid conditions, hot-type mastics should be used. These may be laid over concrete or on firm wooden bases.

Manufacturers' specifications should be followed and care should be taken to see that the correct type for various conditions, such as indoor or outdoor traffic, whether light or heavy, cold storage rooms, etc., is used.

For a sheet asphalt surface hot mix composition, see AREA Specifications for Buildings for Railway Purposes, Asphalt Mastic Floors, Section XXIV, page 6–140 of the Manual.

6. Wood Blocks

Treated wood blocks make satisfactory surfaces for floors of shops and storehouses, and in situations where the floor is protected from the weather, excessive humidity or the building is heated. Wood blocks should be held in place by a suitable curbing. Care should be taken to provide adequate bituminous filled expansion space between blocks.

For materials and treatment, see AWPA Specifications 19b—Interior creosoted wood block flooring.

Wood blocks for platforms and other situations exposed to the weather, should meet AWPA Specifications 16b, Creosoted wood block street paving, net retention 12 pounds of preservative per cubic foot.

Preservative should meet AREA Specifications for Creosote—Grade 1, page 17–13 of the Manual.

Wood blocks should be laid in accordance with AREA Specifications for Buildings for Railway Purposes, Section XXIII—Wood Block Floors—page 6–132 of the Manual.

7. Steel and Iron Plates

Wearing surfaces of steel plates are used on heavy duty wooden platforms. Where tractors are used, the plates should be not less than ⅜ inch thick embedded in a mastic cushion and fastened with counter-sunk screws. If the plates are used over a steel substructure they should be welded to it and to each other. The thickness in this case should be ¾ inch. Plates may also be laid over concrete. Iron plates with special checkered or roughened surfaces are sometimes used to provide better traction, are less abrasive and less corrosive.

Complete and offered for inclusion in the Manual.

Appendix E

(8) RAILROAD TEST LABORATORY—LAYOUT AND TEST EQUIPMENT

C. M. Angel, Chairman, Subcommittee; William T. Dorrance, A. C. Irwin, L. P. Kimball, H. C. Lorenz, Dr. Edward W. Scripture, Jr., L. W. Smith.

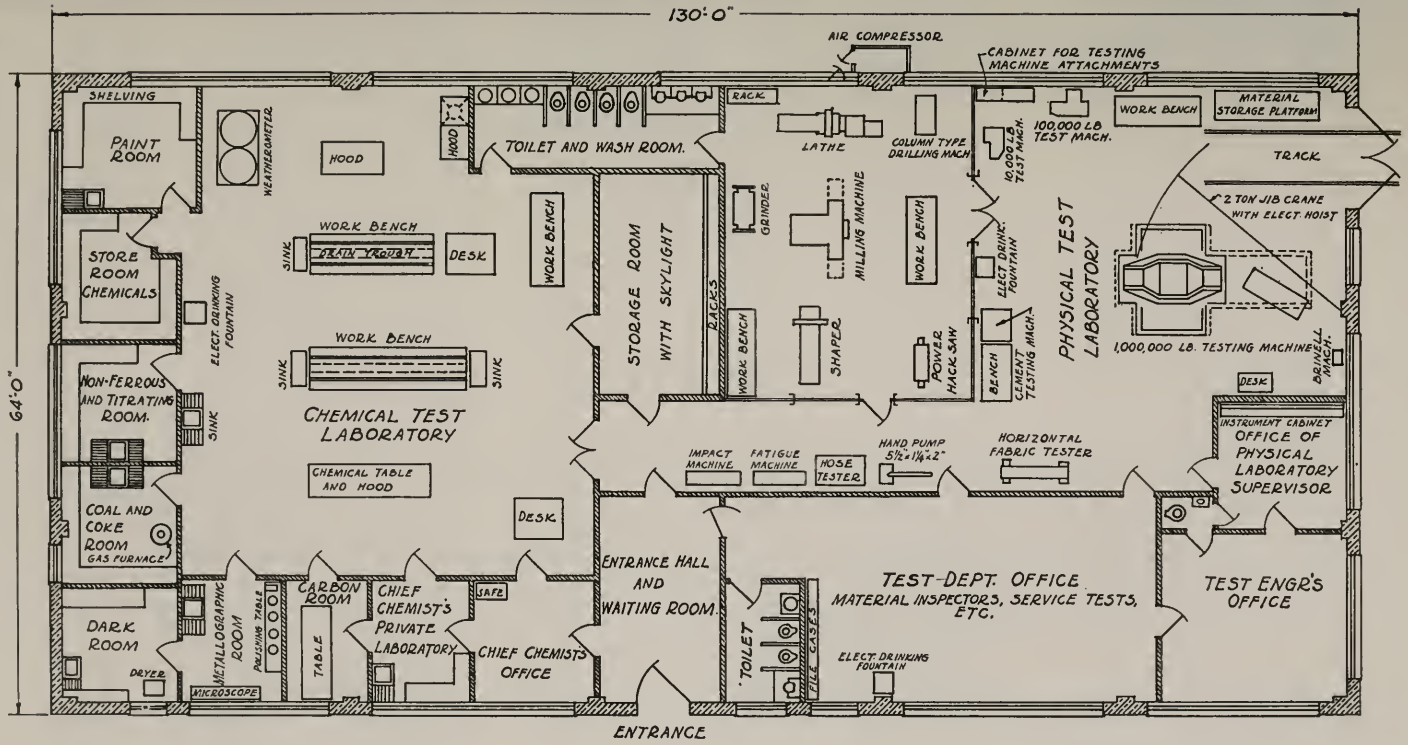
General

Developments have been rapid in recent years and to further this progress the railroads have made and are making extensive research and tests in their own laboratories or in those of others. The test laboratory has a direct bearing on safe and economical railroad operation. Tests and research are necessary to assure the furnishing of proper materials and equipment, and are often helpful in the equitable settlement or successful defense of claims and law suits.

The test laboratory is usually a part of the mechanical department, but is equipped to make investigations for all departments. It should have chemical and physical testing laboratories, a service test department to closely observe new appliances and materials in service, and a material inspection department. When there is a dynamometer car it should be under the control of the test laboratory.

Organization

The personnel generally consists of a chief chemist, a supervisor of the physical laboratory, a supervisor of service tests, a chief material inspector and, when there is a dynamometer car, a dynamometer-car engineer. These men report to an engineer of tests. The remainder of the personnel varies with the amount of work.



FLOOR PLAN OF A TYPICAL RAILWAY TESTING LABORATORY.

Location

The proper location for a test laboratory is at the main repair shop and general stores point, as a large percentage of the work concerns the mechanical and purchasing departments. Thought should be given to possible future expansion of the laboratory.

It is desirable to have the laboratory in a separate building, as shown by the suggested floor plan, but not necessarily a one-story building. In a two-story building the physical department and offices should be on the ground floor and the chemical department on the second floor. If it is desirable to place the physical department in a shop building, the chemical department should be nearby, as the tests of the two departments are closely related. The main test office may be located some distance away without affecting the economical operation of the departments. The building or buildings should preferably be of fire resistant construction with ample daylighting.

Layout

The suggested laboratory floor plan is based on a building of approximately 7,500 sq. ft. net floor area, which is thought to be ample to handle the work of a company operating from 3,000 to 4,000 miles of line. The design is adaptable to varied business conditions. The laboratory provides for a maximum personnel of a chief chemist and eight assistants in the chemical department, and a supervisor, six assistants and one or more machinists in the physical department. The offices should be enclosed with glazed partitions.

The storage room is for materials held pending testing, investigation and distribution, miscellaneous laboratory equipment, old office files and road test records. Access to this room should be provided for both chemical and physical departments, as shown on the plan.

In the chemical laboratory, it is recommended that work usually done in volume, such as paint analysis, metallographic work, carbon determination of steel, coal and coke analysis and non-ferrous work be segregated in small rooms, as shown on the suggested floor plan. This separates the equipment for such testing from the general routine laboratory equipment, and promotes better and more accurate work. Ventilation in the chemical department is essential to expel obnoxious fumes. Exhaust fans of ample capacity should be installed and hoods of acid-proof material provided to carry off fumes.

The chemical laboratory floor should be of concrete, painted or unpainted, with rubber mats in front of work benches, where chemicals may be spilled. The physical laboratory should have a wood-block floor. The floors in the offices should be of hard wood. Wash and toilet room facilities should be convenient to the various departments.

Drain troughs should be installed in the center of the chemical work benches and running their entire length, with connections to the sewer. The chemical and physical departments should be equipped with electric, compressed air, gas and water lines, with outlets at convenient locations. These lines should extend into the separate rooms and be painted identifying colors. Sufficient electric lights and laboratory power circuits, with switches and outlets in accessible and convenient places, are essential.

Physical Laboratory Equipment

The laboratory equipment should include such machine tools as are necessary to prepare specimens for test. Such equipment should be operated by individual motors rather than from line shafting, so that power will not be lost when all or a portion of the machines are idle. The following machine tools are recommended:

Engine lathe	15-in by 60-in.
Drill press	20-in lever type
Grinding wheel	15-in. by 2½-in. double
Shaper	24-in.
Milling machine	No. 3 universal
Power saw	6-in. by 6-in.

If tests of large forgings, axles and other large work are to be made, it would be well to add a 24-in. cold saw and heavy 2-in. diameter drill press. Large material may then be conveniently cut with the cold saw and the specimens drilled out with a 2-in. hollow drill. This machinery may be installed in the physical laboratory or at some other place convenient to the work.

If compressed air is not available from a central plant, an air compressor of ample capacity should be installed in or near the physical laboratory to serve both laboratories. The compressor should be so located that the vibration will not affect the testing apparatus.

If concrete pipe, welded coupler knuckles, rail joints, bridge timbers, etc., are to be tested, a million-pound testing machine is recommended. For metal specimens and plate work a hundred-thousand-pound machine should be provided. For lighter work, such as wire testing, a ten-thousand-pound machine is necessary. All testing machines should be equipped with stress-strain recorders. A hundred-thousand-pound and a ten-thousand-pound proving ring are necessary for checking the testing machines. The million-pound testing machine should be served by a two-ton jib crane, with electric hoist, for handling materials.

The physical laboratory should also have the following test equipment:

Fabric wear-testing machine
Fabric tensile-testing machine
Rubber specimen buffer
Rubber specimen arbor press
Rubber specimen test rack
Hand hydraulic test pump
Hose tester tank
Brinell machine
Shore scleroscope
Rockwell hardness tester
Platform scales
Counter scales
Fatigue machine
Impact machine
Cement testing machine
Molds for tensile briquettes and cylinders
Slump cone
Flow table
Setting time apparatus (Gilmore needle or Vicat needle)
Briquette storage cabinet
Cylinder storage space

Useful smaller instruments are: Huggenberger tensometers, extensometer for .505 specimens, Ames dials reading to 0.0001 in. and 0.001 in., inside and outside micrometers from 1 to 24 in., and an hydraulic gage tester. Cabinets equipped with locks should be provided in the office of the supervisor of the physical laboratory and in the vicinity of the testing machine for the storage of valuable and accurate scientific instruments.

Chemical Laboratory Equipment

The chemical laboratory paint room should be equipped with a paint-spray apparatus and a hood ventilated by an exhaust fan. Approved fire-extinguishing equipment is important. A glassware test apparatus and a centrifuge for the analysis of paints are required. A weatherometer for paint panels should be conveniently located, adjacent to the paint room. Paint test racks for outside-paint exposure tests are located on the roof, with a ladder from the paint room for easy access.

A storage room for chemicals and glassware should be conveniently placed. The non-ferrous and titrating room should have a water still, an electrolytic outfit for non-ferrous analysis, and miscellaneous burrets for titrating. The coal and coke analysis

room should contain a fuel calorimeter, a drying oven, an electric furnace, a hot-plate, a gas-coal ash fusibility furnace, a coal pulverizer and a mortar grinder.

The metallographic and dark rooms should be connected. The former should have a microscope, and a four-disc polishing table. The latter should have equipment necessary for developing and printing photographic plates.

Work benches covered by chemical hoods and benches in main laboratory should be equipped for general work with the following apparatus:

Under hoods for general work:
- Muffle furnace
- Gas burners
- Hot plate

For engine-sand work:
- Motor-driven shaker
- Screens for sieve work

For oils and greases:
- Colorimeter
- Viscosimeter
- Flash-point apparatus
- Centrifuge
- Carbon-residue apparatus
- Pentrometer
- Pour-test apparatus

General Equipment:
- Dry ice machine
- Ball mill
- Electric refrigerator
- Moisture oven
- Air pump
- Balance scales
- Safe and filing cabinets

This report is complete and is offered as information.

REPORT OF COMMITTEE 13—WATER SERVICE, FIRE PROTECTION AND SANITATION

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J. J. Laudig,
O. E. Mace,
T. C. Main,
Ray McBrian,
M. E. McDonnell,
W. A. McGee,
H. L. McMullin,
G. F. Metzdorf,
R. H. Miller,
E. R. Morris,
L. B. Paine,
A. B. Pierce,
W. G. Powrie,
E. M. Grime, *Vice-Chairman;*
S. E. Printz,
W. A. Radspinner,
O. T. Rees,
H. L. Roscoe,
J. A. Russell,
H. E. Silcox,
D. A. Steel,
R. M. Stimmel,
J. E. Tiedt,
C. P. Van Gundy,
H. W. Van Hovenberg,
R. E. Wachter,
J. B. Wesley,
*J. B. Young,
Committee.

* Died July 30, 1938.

To the American Railway Engineering Association:

Your committee respectfully presents its report on the following subjects:

1. Revision of Manual. Progress in study—no report.

2. Types of tannins used in water treatment (Appendix A). Final report, submitted as information.

3. Cause of and remedy for pitting and corrosion of locomotive tubes and sheets, with special reference to status of embrittlement investigations (Appendix B). Progress report.

4. Value of water treatment (Appendix C). Progress report.

5. Progress being made by federal or state authorities on regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR. Progress in study—no report.

6. Hose pipes or nozzles—types and uses (Appendix D). Final report, submitted as information.

7. Trucks for use by water service maintenance forces, collaborating with Committee 27—Maintenance of Way Work Equipment (Appendix E). Final report, submitted as information.

8. Conditioning water for vapor boilers on streamliners and Diesel units. Progress in study—no report.

9. Methods for checking and handling the control of locomotive blowdowns (Appendix F). Final report, offered as information.

The Committee on Water Service, Fire Protection and Sanitation,
B. W. DeGeer, *Chairman.*

James Bertram Young

With a deep sense of sorrow the committee records the passing of J. B. Young on July 30, 1938, age 62 years.

Mr. Young was graduated from the University of Pennsylvania in 1897, and began his railroad career July 25, 1898, when he became assistant chemist of the Philadelphia & Reading, now the Reading Company. On July 1, 1906, he was advanced to chemist,

and was appointed engineer of tests June 1, 1923, which position he held at the time of his death.

In addition to serving on Committee 13—Water Service, Mr. Young was for many years a member of Committee 4—Rail. He was also identified with other engineering societies, having been a member of the American Society for Testing Materials, and chairman of its important Committee A–1 Steel, and later A–2 Wrought Iron.

Mr. Young's many friends in the various technical societies and among railroad men, regret the passing of an amiable gentleman, a capable engineer, and a worthy associate.

Appendix A

(2) TYPES OF TANNINS USED IN WATER TREATMENT

R. M. Stimmel, Chairman, Subcommittee; R. C. Bardwell, W. M. Barr, F. J. Bishop, R. E. Coughlan, H. M. Hoffmeister, C. R. Knowles, J. J. Laudig, H. M. Laudemann, O. E. Mace, Ray McBrian, S. E. Printz.

The meaning of the term tannin does not appear to be fully understood. It is the intention of the report to define the term and describe the principal tannins used in water treatment.

Organic chemicals played a large part in the earliest history of water treatment. The first recorded use of such material was in England in 1821 where it was reported that potatoes, accidentally left in a boiler, removed scale from the boiler sheets. Since that time organic chemicals of all descriptions and kinds have been used in boiler compounds, usually together with soda ash, caustic soda or phosphates in varying combinations. Of these substances, tannins are probably the most widely used.

The term "tannins" is used as synonymous with tannic acid but is more properly a class name for astringent plant products which have certain characteristic color reactions and properties. Although tannins are found in relatively few plants, they are present in plants of nearly every botanical group. From the commercial standpoint the higher group of seed plants and particularly trees are the most important source of the material. Tannin is present among the extraneous components of wood, being considered extraneous material because it can be readily extracted from the woody tissue by suitable solvents and because it is not an integral part of the cell wall.

Chemically, tannins are complex organic ring compounds, the composition of which is not exactly known. Tannins from different plants, or even from different parts of the same plant, vary in properties. It was formerly believed that only one tannin existed, and that the difference in properties resulted from impurities. There are now known to be at least three distinct classes. However, although there is a large amount of general information concerning these materials, there has been very little intensive study of any one, except ordinary tannic acid, and some of the differences in properties may yet be found due to impurities.

Three Groups of Tannins

Since the exact composition of the various tannins is not known, tannins are identified by their characteristic reactions which include the following: (1) astringency; (2) the property of forming a dark blue color or a greenish color with ferric salts; (3) the property of forming a precipitate with gelatine, albumen and some alkaloids; (4) and the property of converting hide into leather. In addition to the reactions which are typical of tannins as a class, there are many properties peculiar to certain tannins. On the basis of these special reactions three groups of tannins are distinguished as follows: depside tannins, ellagitannins, and phlobatannins. Only one or possibly two mem-

bers of the second group are known, and as they are not important in water treatment only the first and third class will be considered in detail.

Depside tannins give a blue-black color or precipitate with ferric salts and form a bloom on leather. They are sometimes called pyrogallol tannins because pyrogallol is formed on heating to certain temperatures. Some of the principal members of this group are ordinary tannin (gallatannin), and tannins from chestnut wood, oak wood and sumac. Ordinary tannin from gall nuts is not used in water treatment and is principally of interest because it has been exhaustively studied and its exact composition is probably known. Oak wood is very low in tannin, containing only approximately 6 percent. The tannin from oak wood, quercin, is to be distinguished from oak bark extract which is a phobatannin. Chestnut wood is exceptionally high in tannins and the extracts have been widely used in water treatment. The liquid extracts contain from 26 to 32 percent tannin and the powdered extract up to 70 percent. Chestnut extract is probably closely related to ordinary tannin. The tannin is found in the pores or ducts separating the wood fibers and is distinguished from other wood tannins because it is present in the wood as a glucoside.

Phlobatannins yield green colorations with ferric salts and give distinctive red precipitates, known as phlobaphenes, when heated with aqueous solutions of mineral acids. One attempted differentiation between tannins is based on the decomposition of phlobatannins to catechol, the members of this group sometimes being called catechol tannins. This is not correct because some phlobatannins do not form catechol.

There are a very large number of phlobatannins, the principal ones of interest in this report being hemlock extract, chestnut oak extract, quebracho and cutch. Chestnut oak extract is prepared from the bark of certain oak trees. This bark is low in tannin and the extract only contains from 18 to 20 percent of the material. Solid hemlock extract contains 58 percent tannin. Quebracho extract is prepared from a hardwood tree, Quebracho Colorado, which is indigenous to South America. The wood contains from 18 to 24 percent tannin and the solid extract from 63 to 67 percent. It is sold on the basis of 65 percent. This product is one of the most astringent of tannins. It is sparingly soluble in water and is frequently sulphited in the preparation of its extracts. Cutch or catechu is a term applied to extracts obtained from several plants which are native to Asia and parts of Africa. The cutch usually bears the name of the country or plant from which it was obtained. These extracts are usually rich in tannins and closely related chemically. The name was originally applied to extracts from the wood of two species of acacia, known as ordinary or black catechu. Gambier, pale catechu, is similar in composition to ordinary catechu. It is prepared from the leaves and young twigs of certain tropical cinchonaceous plants. Bark from mangrove trees is also used in preparing one of the tannins called cutch. Cutch has been used extensively in water treatment.

Use Extracts for Water Treatment

Although large amounts of pure tannin are used industrially, only the extracts are used in water treatment. Tannin is extracted or leached from tannin bearing material, usually with hot water. The extract is then clarified and is usually concentrated in vacuum evaporators either to a viscous liquid or a solid. In addition to tannin, the extract contains such substances as sugar, coloring matter, etc. These impurities may have some influence on the action of the material. In addition to the extracts already listed, a by-product of the leather industry called runaway extract is sometimes used in water treating materials. This by-product usually contains from 15 to 30 percent tannin. It should be distinguished from spent tan which contains less than one percent tannin.

Sulfite cellulose extract might also be mentioned because of its inclusion with tanning materials. This extract is obtained from the waste sulfite liquor which is produced during the manufacture of pulp by the sulfite process. The extract contains the ligneous matter dissolved from wood by the sulfite solution. When tested by the hide powder method about 25 percent of the material is absorbed. It is not claimed that the absorbed material is tannin.

Tannins are frequently found in proprietary boiler compounds and are often used with soda ash and caustic soda in wayside treatment. They are sometimes used following the complete treatment or softening of water for boiler purposes. Four advantages have been claimed in the use of tannins, namely: (1) The incrustation of pipe lines and boiler feedwater lines may be reduced or prevented; (2) pitting due to oxygen may be inhibited; (3) deposits or scale on boiler sheets and tubes may be modified; (4) intercrystalline corrosion may be prevented under certain conditions. The exact action of tannins and the benefits to be expected from their use have not been studied exhaustively, except in special cases. Therefore, general rules covering the applicability of tannins in water treatment or for the selection of the type most suitable under various conditions cannot be given at the present time. Attention is called to the fact that, on account of the more or less distinct individuality and varying tannin content of the various extracts, tannins should not be accepted or used indiscriminately.

Future reports by your committee will no doubt be presented on the subject of tannins as additional information becomes available.

The report is submitted as information.

Appendix B

(3) CAUSE OF AND REMEDY FOR PITTING AND CORROSION OF LOCOMOTIVE BOILER TUBES AND SHEETS

With Special Reference to Status of Embrittlement Investigations

R. E. Coughlan, Chairman, Subcommittee; R. C. Bardwell, W. M. Barr, J. H. Davidson, E. M. Grime, J. J. Laudig, H. M. Laudemann, O. E. Mace, Ray McBrian, W. A. McGee, O. T. Rees, H. L. Roscoe, R. M. Stimmel, J. B. Wesley, J. B. Young.

During the past year excellent results have been accomplished in the study of the elimination of Intercrystalline Corrosion, formerly called "Embrittlement" or "Caustic Embrittlement." The excellent work done at the United States Bureau of Mines under the joint sponsorship of the AREA in co-operation with some six other associations has definitely indicated that this type of boiler trouble can be eliminated by the use of the organic material known as Lignin.

As it is a very difficult matter to determine the presence of this material in steam boilers, extensive research was conducted at the United States Bureau of Mines to determine definitely ways and means by which the presence of this material could be confirmed. Experiments have proved that the following method is the most satisfactory yet discovered for the determination of the presence of Lignin in steam boilers.

COLORIMETRIC METHOD FOR THE DETERMINATION OF LIGNIN

The analytical method here described depends on the reducing or oxygen-absorbing power of lignin and tannins. The tryosin reagent of Folin and Denis[1] is reduced to give a blue solution of a color density that varies with the concentration of the lignin.

[1] Otto Folin, and W. Denis. Jour. Biol. Chemistry, Vol. 12, pp. 239–243 (1912) (Tyrosin Method).

The reagent is sensitive to small amounts of lignin and is therefore particularly suitable for boiler and feed-water analyses. This method has been carefully tested in the laboratory as well as on a number of samples from operating boilers and, in general, it should give satisfactory results. The method is rapid and simple so that it may be used as a routine procedure.

Solutions Needed

(1) *Sodium tungstate-phosphomolybdic acid*

One hundred grams of sodium tungstate, 20 grams of phosphomolybdic acid, and 50 cc of 85 percent phosphoric acid are dissolved in 750 cc of water. The liquid is boiled under reflux for 2 hours, cooled and made up to 1 liter.

(2) *Saturated sodium carbonate*

Add enough sodium carbonate to 1 liter of water to supersaturate the solution with respect to $Na_2CO_3.10H_2O$ and allow excess to crystallize.

(3) *Lignin comparison solution*

This solution represents the "standard" for the method and should be made up of exactly the same material that is fed to the boiler.

If waste sulfite liquors are used for the boiler feed they should contain about 50 percent dissolved solid. Weigh out a 10-gram sample from a well shaken representative portion of the feed solution and dissolve in a liter of water. Pipette out 10 cc of this solution and dilute to a liter. This latter solution is the comparison or standard solution and it contains 100 ppm of the 50 percent solution used in the boiler feed.

If powder obtained from waste sulfite liquor is used for the boiler feed, weigh out a 10-gram sample and dissolve in a liter of water. Pipette out 10 cc of this solution and dilute to a liter.

Procedure

(1) A 50 cc filtered, clear, and cooled sample of boiler or feed water containing less than 20 ppm of sulfite waste liquor is put in a 100 cc Nessler tube. If the water contains more than 20 ppm a smaller sample should be taken and diluted to 50 cc.

(2) Make up 2 or 3 similar samples from the comparison solution to contain lower and higher concentrations of lignin than the unknown sample. They should also be diluted to a total volume of 50 cc.

(3) Treat each known and unknown with 2 cc of the sodium tungstate-phosphomolybdic acid solution. Stir and allow to stand 5 min. Add 10 cc of saturated sodium carbonate to each sample, stir and allow to stand 10 min.

(4) Match the blue color of the unknown with the knowns to estimate the amount of lignin.

Interference

This method of analysis is free from interference by sulfate, silicate, chloride, phosphate, hydroxide, and sulfite, as well as most of the positive ions encountered in water samples. Ferrous iron will, however, cause interference. Fortunately, in most alkaline boiler waters the concentration is too low to cause difficulty. If a small amount of iron is present it may be desirable to allow the sample to settle for a few hours before an aliquot is taken for analysis. This will cause some oxidation of the iron and allow it to precipitate. The lignin itself will not suffer appreciable oxidation at room temperature. In the analysis of a few boiler water samples it has been found that there is a tendency

for the slow precipitation of calcium carbonate. This carries down some lignin, and if the sample is analyzed immediately on removal from the boiler it shows higher concentration of lignin than it will show a few hours later. This sample may also be settled and filtered to avoid difficulty. To eliminate interference from both iron and calcium carbonate, a filtered, clear sample has been specified in the procedure.

The method of analysis suffers interference from some organic materials, especially phenolic compounds that might be present in some feedwaters. A blank should be run on the feedwater if appreciable interference is suspected. Highly colored boiler waters may also cause some difficulty.

Tannin materials, including cutch and quebracho, may also be determined by this method. The comparison solution should, of course, be made from the material fed to the boiler. One ppm of the tannins will produce as much color as 4 to 7 ppm of lignin. In general it would not seem desirable to add lignins and tannins to the boiler feed simultaneously since this would complicate the analysis.

Concentrations to Be Maintained in the Boiler

On the basis of a waste sulfite liquor containing 50 percent dissolved solid the experimental work now indicates that it is desirable to maintain a concentration of this waste liquor in the boiler water equivalent to 15 or 20 percent of the total sodium hydroxide alkalinity. As a precautionary measure this alkalinity might well be measured to the methyl red or methyl orange endpoint.

For some reason as yet unknown the dry powders obtained from the waste sulfite liquors are not twice as effective as the solutions containing 50 percent dissolved solid. Therefore, it is desirable, even though the standard solution is made up with dry powder, not to let the concentration in the boiler water on the basis of this standard drop below 15 percent of the sodium hydroxide alkalinity.

At the present time there is no method of determining the influence of various lignin materials on intercrystalline cracking other than actual tests for their effect in preventing cracking. For that reason it is best to use materials from sources that have already been tested and sources that can furnish a uniform, controlled grade for addition to the feedwater.

If it is desired to use either Philippine cutch or quebracho instead of the lignin compounds for preventing embrittlement, this can be done. Experimental results indicate that on the basis of the dry powder a concentration equal to about 15 percent of the sodium hydroxide alkalinity should be maintained in the boiler water.

This report is offered as information.

Appendix C

(4) VALUE OF WATER TREATMENT

C. R. Knowles, Chairman, Subcommittee; R. C. Bardwell, R. W. Chorley, R. E. Coughlan, W. L. Curtiss, R. N. Foster, C. H. Fox, E. M. Grime, J. S. Hancock, R. L. Holmes, T. C. Main, H. L. McMullin, R. H. Miller, W. G. Powrie, O. T. Rees, J. B. Wesley.

The committee has collected a large amount of data on this subject during the past year. Through the courtesy of the manufacturers of boiler feedwater treatment, considerable research work is being carried on regarding the ratio of scale deposit to the total hardness of certain waters and the influence the sulphate carbonate ratio may have

on the deposit of scale. These studies are not complete, and this year's report is confined to a review that provides an historical background for a monograph on the value of water treatment submitted by Mr. Curtiss.

It has been nearly 70 years since the first attempt was made to place a value on the treatment of water for locomotives. The American Railway Master Mechanics' Association began a study in 1870 of the cost of locomotive operation in hard water territories in the middle western states as compared with locomotives using the comparatively soft waters of New England. The conclusion reached after about three years of study was that the cost of operating the locomotives using the harder water was about $750 per year greater for each locomotive. The locomotives in general use at that time weighed approximately 70 tons and were operated at pressures from 140 to 150 lb.

The first reference to water treatment by Committee 13 was made in the Proceedings in 1901, Vol. 2, and comprised a summary of replies to a questionnaire regarding water conditions, methods and costs of treatment from 71 railroads.

Volume 5 of the Proceedings (1904) included a rather comprehensive report which discussed the character of the impurities found in boiler water, methods and cost of treatment, together with a list of railroads that had installed water treating plants up to that time. The committee also discussed in detail the benefits from the use of soft water in locomotive boilers.

The following year, in Vol. 6, the committee made another rather extensive report on water softening in which the value of water treatment was further discussed and definite figures presented showing the results accomplished on various railroads through water treatment.

Water treatment methods in use at that time were discussed in further detail in Vol. 8. The report covered the relative economies of the continuous and intermittent water softeners, reagents used in treatment, and a formula to determine the minimum content of scaling solids in a water which would justify the expense for constructing water treating plants.

It is interesting to note the data submitted by the subcommittee regarding the rate of deposition of scale, which follow:

> The average locomotive with an average steam coal evaporates approximately one gallon of water per square foot of heating surface per hour. The following table shows the number of hours service required to make 1/16-in. scale for various amounts of incrusting matter:

Pounds incrusting solids per 1,000 gal. water	1	2	3	4	5	6
Hours of service to accumulate 1/16-in. scale	781	391	260	195	156	130

The report of the committee in 1908, Vol. 9, was devoted entirely to a discussion of water treatment, including a summary of Bulletin No. 11 of the Engineering Experiment Station of the College of Engineering, University of Illinois, on "The Heat Transmission Loss due to Boiler Scale and its Relation to Scale Thickness." This report was in the form of a monograph by Professor E. C. Schmidt and incorporated his remarks before the Western Railway Club.

The conclusions presented in this report follow:

1. The loss in heat transmission due to scale up to ⅛ in. in thickness may vary in individual cases from insignificant amounts to as much as 10 or 12 percent.
2. That the loss increases somewhat with the thickness of the scale.
3. That the mechanical structure of the scale is of as much or more importance than the thickness in producing this loss.
4. That chemical composition except insofar as it affects the structure of the scale has no direct influence on its heat transmitting qualities.

The committee continued the study and in 1914, Vol. 15, presented a report based upon the comparative operating cost of a 106-ton locomotive using a water containing 20 grains per gal. of scale-forming solids as compared with a 7-grain water. It was estimated that this locomotive would have a mileage of 45,000 miles per year, a coal consumption of 4,500 tons and a water consumption of 7,500,000 gal. The saving per locomotive per year on this basis was $977, and as the difference of 13 grains of hardness in 7,500,000 gal. of water represented 13,929 lb. of incrusting solids the saving of $977 per locomotive represented a value of 7 cents per pound for the scale matter removed from the water.

In arriving at this figure the committee took into consideration the following features:

(a) The loss of fuel due to the insulating effect of the scale on flues and other heating surfaces.

(b) Renewal of flues on account of scale accumulation and injury to flue ends from repeated calking.

(c) The cost of labor used in calking flues and in other enginehouse boiler repairs.

(d) The loss of engine time during period of boiler and firebox repairs.

No consideration was given to other items entering into the expense of maintaining locomotive boilers, such as renewal of fireboxes and sheets, broken staybolts and cracked sheets nor was any consideration given to the removal of suspended matter.

As the cost of operating and maintaining locomotive boilers increased it became necessary to revise the figure of 7 cents, and following preliminary studies the value of 7 cents per pound was increased to 13 cents in 1920. A further check on the value of water treatment, as represented by the figure of 13 cents per pound for solids removed, was made in 1925, Vol. 26. This study was based on the comparative cost of operating and maintaining locomotives on the Iowa division of the Illinois Central for the years 1920–21 and 1922–23, compared. The costs were taken from the standard accounts. These figures showed that the average cost of operation and maintenance for all engines on the Iowa division decreased $3,536.65 per engine during the latter period.

In a discussion of these figures in committee the question was raised as to the value of a direct comparison of the figures shown in the standard accounts, and it was decided to submit a further report, making adjustments in the figures for equal amounts of work. A supplementary report showing the revised figures was presented the following year in Vol. 27. The result of this summary on adjustment of figures indicated that the total decrease in expense per locomotive attributed to water treatment was $2,732.19, this figure being based on the average cost of operating and maintaining locomotives over a three-year period of treatment 1922, 1923 and 1924 inclusive. Approximately ninety locomotives were in service during the latter period. Therefore, the saving of $2,732.19 per locomotive per year represented a total annual saving of $245,897.

During 1922, 1923 and 1924 the average amount of treated water used annually by these locomotives was 378,000,000 gal., from which it is calculated that 1,134,000 lb. of solids were removed. Therefore, the decreased cost of locomotive operation and maintenance represented a value of $0.216 for each pound of scale-forming solids removed by water treatment. As a result of these studies the committee reached the conclusion that placing a destructive value of 13 cents per pound on the solids removed in treatment was a safe figure for the reason that it was an underestimate. It should be borne in mind, however, that during the first period a large part of the water was treated as compared with the second period when all water was treated. Therefore, had the com-

parison been made with a period during which all water used had been untreated the saving per pound would have been greater.

The value of 13 cents per pound for scale-forming solids removed from locomotive boiler water was adopted nearly 25 years ago from data previously obtained, based on the operation of a 106-ton locomotive representing a value of $16,000, at which time a set of flues was valued at $234, compared with a locomotive representing a value of about $100,000 and a set of flues (including super-heater tubes) representing a value of $1,400.

Studies concerning the value of water treatment appear to have been devoted entirely to the effect of scale deposits occurring from matter in solution, little, if, any consideration having been given the effect of suspended matter or the value of corrosion prevention. Reference to scale formation has been rather general without regard to the constituency of the scale with the possible exception of Dr. Schmidt's experiments.

There is undoubtedly much to be learned in regard to the ratio of scale deposit as compared to the total hardness as well as the influence the sulphate carbonate ratio solids may have on scale deposits. Mud and suspended matter is also an important factor in scale deposition and must be given consideration.

It is interesting to note that in all of the investigations conducted regarding the value of water treatment none have been based upon a direct comparison of results obtained with treated water and untreated water. The first investigation as conducted by the Master Mechanics' Association in 1870 was on waters of unknown character. The value of 7 cents, as established by this committee in 1914, was based on operating results using a 20-grain water as compared to a 7-grain water. The report of the committee in 1926 was based on a comparison of partially treated with completely treated water. The monograph which is presented as a portion of this report is a comparison of waters having a hardness ranging from 7 to 16 grains as compared to a water having a hardness of 3.4 grains.

Much has been accomplished toward improving boiler water conditions during the past 40 years. At the same time there are still 200 billion gal. of water being used annually by the railroads which can be profitably treated. There is also opportunity for estimated annual saving of $12,000,000 through the elimination of corrosion in locomotives by the proper treatment of boiler water, and the committee hopes to formulate data on the treatment of water that will serve as an accurate yardstick and be acceptable to all railroads.

This report is offered as information.

VALUE OF WATER TREATMENT

A Monograph

By W. L. Curtiss
Mechanical Engineer, New York Central Railroad

An investigation was begun in 1924, for the purpose of ascertaining on the New York Central Railroad, the locations where locomotive water supplies were of such character as to require treatment, the kind of treatment necessary in each case, the proper method of administering such treatment and if the benefits to be derived would justify the expense.

It was realized at the outset that the first and most important thing to be determined was how much loss to the railroad is occasioned by bad water, as a measure of

the value of the water treatment to be proposed. Unless this could be determined with at least approximate accuracy, all other data obtained would be useless.

The report prepared by Mr. H. W. Faus, engineer of tests, included a tabulation of the results of a mineral analysis of every water supply (there being a total of over 600 supplies), the quantity of water of each consumed, the pounds of scale forming salts contained therein, the character of treatment recommended with the estimated cost and savings to be expected. However, it is the purpose of this article to present such data only as had a bearing on the value of water treatment.

The Water Service committee of the AREA concluded in 1924 that for each pound of incrusting solids allowed to get into a locomotive boiler, the loss to the railroad would amount to at least 13 cents, but it was decided to make an independent study of the New York Central's specific conditions and records to determine, if possible, the actual loss from the use of bad water without resort to a formula derived from data collected on other railroads under a different set of conditions.

For comparative study four districts were selected in which during 1923 there was little or no overlapping of locomotive runs. They were the Ohio Central Lines, which have the worst waters, the Line West with waters somewhat better, the Line East with still better waters, and the Boston & Albany Railroad where the waters are very good. Statements were then obtained, for each of the four districts, for the year 1923, showing the actual number of tons of locomotive fuel consumed, the actual direct labor and material cost of boiler repairs and also complete locomotive mileage statistics. The results may be summarized as follows:

Table No. 1

Costs of Boiler Repairs and Locomotive Fuel Vary With Quality of Water

	B. & A.	*Line East*	*Line West*	*O.C. Lines*
Average quality of water-incrusting solids-grs. per gal.	3.40	7.20	11.51	16.06
Cost of boiler repairs—cents per locomotive mile	2.98	5.05	5.76	5.83
Consumption of locomotive fuel—pounds per million pound-miles tractive effort	4,201	4,232	4,457	5,099

It will be noted that, without exception, the actual cost of boiler repairs per locomotive mile was greater where the quality of the water was poorer. This could hardly be a mere coincidence. Doubtless other factors contributed to some extent to the creation of these wide differences in cost, but if there was any good reason other than bad boiler water to account for the fact that the unit cost of boiler repairs on the Line West was nearly twice as great as on the Boston & Albany, such reason was not apparent.

The fuel consumption likewise invariably increased as the purity of the water decreased. In selecting the unit of measure to be used in comparing fuel consumption, consideration was given to the gross ton-mile, the locomotive-mile and the tractive effort pound-mile basis.

The gross ton-mile basis was rejected because it means very little when comparing fuel consumption in one territory, which may have comparatively level grades, with another territory having heavy grades, such as are found on the Boston & Albany for example. If it were a matter of comparing the average fuel consumption for one year with that for another year over the same territory, then the gross ton-mile basis would undoubtedly be the most accurate.

The locomotive-mile, which is generally accepted as a basis for comparing locomotive maintenance cost, was regarded as a less fair basis for comparing fuel consumption. If the average size and capacity of power in the different territories were about the

same, the fuel consumption per locomotive-mile, other things being equal, might be expected to be fairly constant; but when comparing fuel consumption on the Ohio Central Lines, where the tractive effort per locomotive averaged only 35,776 lb. with consumption on the Line West, for instance, where the average tractive effort per locomotive was 43,018 lb. this factor must be taken into consideration. The comparison was, therefore, made upon the basis of pounds of coal per million pound-miles of tractive effort.

From the figures shown in Table 1 above, a few simple calculations will disclose the total saving that would have been effected on the Ohio Central Lines, Line West and Line East respectively, had it been possible to keep the cost of boiler repairs per engine-mile and fuel consumption per tractive-power-mile as low as the averages actually attained on the Boston & Albany, which had the benefit of good water. The results and summary of these calculations are shown in Table 2.

TABLE 2

	B. & A.	*Line East*	*Line West*	*O.C. Lines*	*Total N.Y.C.R.R.*
Boiler Repairs					
Boiler repairs—Cost per locomotive mile, cents	2.98	5.05	5.76	5.83	.....
Total loco. miles 1923 ...	11,352,262	56,970,588	30,465,791	6,038,697	.....
Boiler repairs, excess cost per loco. mile over B&A. cents ...	.....	2.07	2.78	2.85	.....
Boiler repairs, total excess cost over B&A, 1923	.....	$1,179,291	$846,949	$172,103	$2,198,343
Fuel Consumption					
Lbs. coal per million (lb.) tractive-power-miles, 1923	4201	4232	4457	5099	.....
Total loco. tractive-power-miles, 1923 mill. lb..	413,336	2,047,912	1,225,077	206,317	.....
Lb. coal per million (lb.) tractive-power-miles, excess over B&A	.....	31	256	898	.....
Lbs. coal, total excess over B&A 1923	.....	63,485,272	313,619,712	185,272,666	.....
Average cost coal per ton 1923–1924–1925* ...	.....	$4.15	$3.51	$2.56	.....
Total excess cost coal over B&A, 1923*	.....	$131,732	$550,403	$237,149	$919,284
Summary					
Total excess cost boiler repairs over B&A, 1923	.....	$1,179,291	$846,949	$172,103	$2,198,343
Total excess cost loco. fuel over B&A 1923	.....	131,732	550,403	237,149	919,284
Total excess cost over B&A, 1923	.....	$1,311,023	$1,397,352	$409,252	$3,117,627

* The actual cost of coal per ton in each of the three territories in question was averaged for the years 1923, 1924 and 1925, and these average prices used for computing the total excess cost. The use of 1923 prices as a basis would have led to misleading conclusions because prices paid during the year were higher than the average for the last three years.

If it were assumed that with equally good boiler water the Line East, Line West and Ohio Central Lines could reduce their expenditures for boiler maintenance and locomotive fuel to the Boston & Albany unit-level, and there appears to be no reason to doubt

that they could, then it must be concluded that the loss due to bad water on the New York Central alone amounted to $3,117,627 for the year 1923. It is interesting to observe how the actual losses due to bad water, as computed above, compare with the losses which would have been indicated by the AREA formula of 13 cents per pound of incrusting solids. The comparison follows:

	Line East	*Line West*	*O.C. Lines*	*Total*
Estimated loss in 1923, based upon AREA formula and comparison of water with B & A	$1,034,600	$1,252,348	$330,727	$2,617,675
Actual loss, year 1923, based upon comparison of unit costs with B & A	$1,311,023	$1,397,352	$409,252	$3,117,627

It will be noted that, in each case, the actual loss was greater than the estimated loss based on the AREA formula, the average excess being 19 per cent.

As a further check on the AREA formula the Line East has been assumed as a standard, both as to quality of water and unit costs, and the excess cost on the Line West and O.C. Lines, compared with the Line East, has been computed. Here again the actual loss exceeded the loss based on the AREA formula, in each case. The result follows:

	Line West	*O.C. Lines*
Estimated excess cost over Line East, based upon AREA formula, year 1923	$665,629	$231,461
Actual excess cost over Line East based upon comparison of unit costs, year 1923	$700,058	$276,064

No account has been taken, either in the AREA formula or in the investigation reported above, of the more or less intangible losses which result from bad water. For example, the figures showing increased cost of boiler repairs do not reflect any part of the loss, which must have resulted to the railroad from the fact that while these repairs were being made the locomotives were out of service. Also, when an engine steams poorly it may delay its own and other trains and cause a loss to the railroad much greater than the cost of the actual excess fuel burned by that particular locomotive. Furthermore, no overhead has been included and, therefore, all of the figures cited herein represent a direct out-of-pocket loss.

On the other hand, no account was taken in this investigation, of the possible increase in fuel consumption that would result from the boiler water blow-down which must accompany water treatment. Accordingly, it will be of interest to include the results of later tests on passenger locomotives operating on treated water and equipped with a continuous type of boiler water blow-down device.

Observations were made on runs between terminals at Cleveland, Ohio, and Toledo. The orifice in the blow-down device was ¼ in. in diameter. The blow-down discharge was piped through the water space in the tender, to condense the flash steam and collected in a tank car back of the tender to permit accurate measurement at the end of the trip. The boiler pressure during the tests averaged between 210 and 225 lb. The temperature of the blow-down water was measured inside the boiler as near as possible to the blow-down valve.

A gage was tapped into the blow-down line on the delivery side of the blow-down valve and an ordinary valve introduced in the line beyond the gage so that any desired back pressure could be maintained on the blow-down discharge. It was determined that when the blow-down discharged to atmosphere through a separator, in ordinary regular operation the average back pressure was 117 lb. Hence, during the tests this same back pressure was constantly maintained by operation of the hand valve.

The blow-down valve is automatically controlled from the feed pump discharge line and is therefore open whenever the feed pump is in operation. The Class J–1 locomotives under test were part of a group operating between Cleveland and Chicago. It was observed that the blow-down valve was open 80.3 percent of the time en route and the average monthly mileage per locomotive at that time was 7,763. The mileage per trip was 334. The tests showed a blow-down rate of 82 to 92.7 lb. per min. during the actual time that the blow-down valve was open. The calculations of the loss of fuel due to the blow-down were based on the maximum rate of 92.7 lb. and were as follows:

CALCULATION OF LOSS CHARGEABLE TO CONTINUOUS BLOW-DOWN
J–1 LOCOMOTIVES—8/32-IN. ORIFICE

1.	Average discharge of water, incl. steam flash, per minute	92.7
2.	Average temperature of water discharged	311 deg. F.
3.	Heat in 1 lb. water at 311 deg. F. in B.t.u.	280.9
4.	Average temperature, feed water, estimated	200 deg. F.
5.	Heat in 1 lb. water at 200 deg. F. in B.t.u.	167.94
6.	Average boiler efficiency, boiler only	57 percent
7.	Average heat value, 1 lb. coal as fired (62 samples)	13,178 B.t.u.

Then—$\frac{(280.9 - 167.94)\ 92.7}{13{,}178 \times .57} = 1.39$ lb. coal per minute.

$1.39 \times 60 = 83.4$ lb. coal per hour.

Average time enroute between Linndale and Chicago ..... 7.7 hrs.
Average ratio-time of blow-down in operation to time enroute 0.803
Mileage Linndale to Chicago 334

Then—$7.7 \times 0.803 \times 83.4 = 516$ lb. coal per run of 334 miles

and $\frac{516}{334} = 1.54$ lb. coal per locomotive mile

Average cost of coal on tender $2.98 per ton

Therefore $\frac{1.54 \times 1000}{2000} \times \$2.98 = \$2.29$ per 1,000 locomotive miles.

Average mileage made by N. Y. C. Class J–1 locomotives west of Cleveland for one month = 7,763.

Therefore $\frac{7763}{1000} \times \$2.29 = \$17.78$ average per locomotive per month.

It has been demonstrated conclusively that with the use of treated water and the continuous blow-down these locomotives can be operated 30 days between washouts, while previously they were washed out on an average of four times a month, thus saving the expense of three washouts per month. Data collected from various terminals indicates an average cost of washing out a locomotive boiler is $12. This includes $5 for labor while the other $7 covers the value of the water for refilling the boiler, the cost of refueling, the cost of disassembling the gage glass and connections and cleaning, the checking of the safety valve and the regrinding of the boilers and feed line checks, all of which are done every time the boiler is washed, regardless of the number of washings per month. Hence the saving in washout expense per locomotive per month is $36 or double the value of the fuel loss due to the blow-down.

The blow-down device tested, with its orifice 8/32 in. in diameter, has the largest opening that has been used. It has been found since, that an orifice 7/32 in. in diameter is large enough for nearly all cases, and with this, the fuel loss is reduced below that shown above.

Conclusion

It is seen that in the case of the New York Central, at least for the year 1923, the facts presented support the AREA formula to a degree that is remarkable, and also indicate that the formula is conservative.

Appendix D

(6) HOSE PIPES OR NOZZLES—TYPES AND USES

W. A. Radspinner, Chairman, Subcommittee; W. L. Curtiss, J. P. Hanley, H. F. King, G. F. Metzdorf, W. A. McGee, L. B. Paine, A. B. Pierce, J. A. Russell, H. E. Silcox, H. W. Van Hovenberg, R. E. Wachter.

As soon as man invented contrivances to create fires, he found himself facing the necessity for inventing schemes to extinguish them. In the early history of Rome, when the city was being rebuilt after it had been burned by the Gauls in 390 B.C., every citizen was required to keep a machine for extinguishing fire in his home.

Your committee with this historical background, has attempted to bridge the gap between 390 B.C., and the present day by reference to the development of what is now standard equipment. Probably the most important experiments were conducted by John R. Freeman, the results of which were published in his Paper No. 426, ASCE, Experiments Relating to Hydraulics of Fire Streams, 1889; and his Paper No. 479, ASCE, The Nozzle as an Accurate Water Meter, 1891.

It is well known that a jet of water issuing from a nozzle exerts considerable reaction, depending on the momentum of the water. This became an important factor of design, as the pressure of the water supply mains became greater.

The Underwriters pipe, shown in Fig. 1, is designed along the lines of the nozzle used by Freeman. Its long, smoothly tapering sides lessen the reaction from the discharge and make it easier to handle. It is also used with a piezometer gage by the underwriters' inspectors to measure the discharge of fire pumps.

It will be noted that Underwriters pipe is made in two sections. The discharge end is made with various openings and has the same outside diameter and number of threads per inch as the 1½-in. standard hose coupling. This will permit the coupling of a 1½-in. fire hose, direct to the nozzle of a 2½-in. hose-stream play-pipe. This is desirable inside buildings as the smaller hose can be used with less water damage on small fires and is also much more easily controlled in inaccessible places.

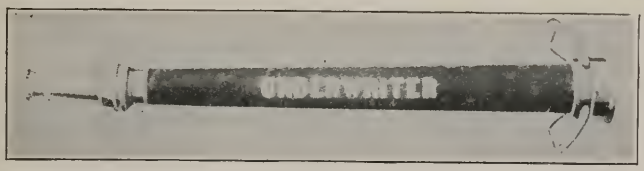
National Board of Fire Underwriters and the Factory Mutual Laboratories, taking these things into consideration, have experimented with various shapes and types of nozzles so that there are available nozzles or play-pipes for almost every purpose. They are designed to handle high-pressure fire streams or spread a fog or mist, depending on the type of fire to be extinguished.

Fig. 1—The Underwriters nozzle should be used by shop fire brigades, and

(1) Kept attached to the hose in hose houses;
(2) Mounted on each hose cart,
(3) For foam generating outfits where oil, paint and gasoline are stored.

Fig. 2 shows the type of nozzle used on standpipe wall reels or racks for inside protection; also on Coppus cold water fire pumps on locomotives. It is available in several lengths for all standard size fire hose. The size most commonly used is that shown in the table under Fig. 2. This type of nozzle is for use inside buildings where 2½-in. and 1½-in. hose and standpipes are used, as in office buildings, warehouses, piers and shop buildings, where the hose is kept on wall reels and racks.

Fig. 3 illustrates what is known as the Boston play-pipe, which is used for high-pressure fire streams. Its leather handles, with swivel connections, afford some protection from electric currents should the stream come in contact with live wires. It can be purchased with any type of shut-off or control nozzle tip. The discharge openings in this type of nozzle, with plain tip, range from 1⅛ in. to 1¾ in. The length over all



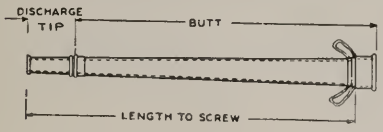


TABLE		
HOSE SIZE	LENGTH TO SCREW	DISCHARGE
UNDERWRITERS STANDARD PLAY PIPE		
2½"	30"	1⅛"

DISCHARGE ENDS CAN BE OBTAINED WITH 1¼, 1½ AND 1¾" DISCHARGE OPENINGS WHICH WILL FIT STANDARD BUTT

FIG. 1.—Underwriters Standard Play Pipe.

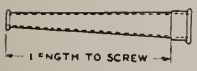


TABLE		
HOSE SIZE	LENGTH TO SCREW	DISCHARGE
PLAIN NOZZLE		
1½"	12"	½"
2"	15"	11/16"
2½"	15"	13/16"
2½"	18"	1"

FIG. 2.—Plain Nozzle.

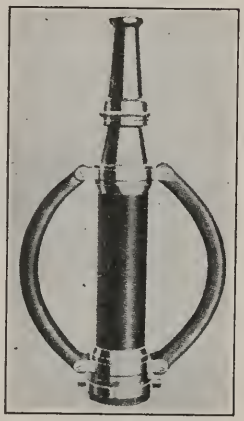
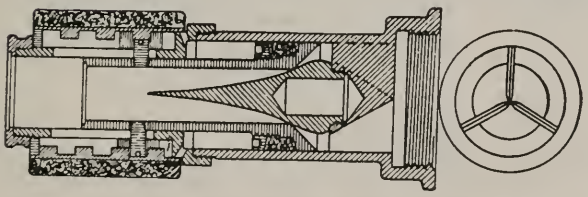


FIG. 3.—Boston Pipe.



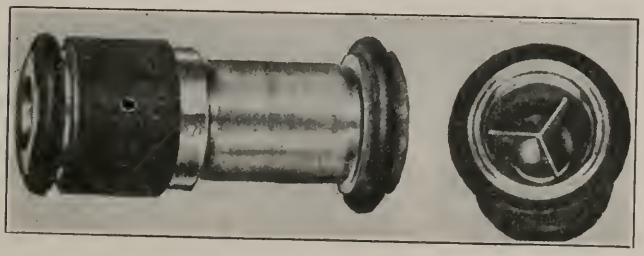


FIG. 4.—Control Nozzle.

ranges from 20 to 25 in. This type of nozzle is for use where there are high-pressure water lines and high-voltage electric wires as in large powerhouses or substations usually found in large shop properties and coal piers.

Fig. 4 is known as a control nozzle. With it a stream may be varied to any size from ¼ in. to 1¼ in. by turning the sleeve right or left. It eliminates changing the tips, as is necessary on the Underwriters pipe, shown on Fig. 1. It can also be closed and thus acts as a shut-off nozzle.

This type of nozzle is rather short and the butt end is threaded to fit directly onto the standard 2½-in. fire hose. It is not easy to direct a high-pressure stream with it as it is with the Underwriters or Boston play-pipes, but on account of its adjustable size hose stream, it is very popular with city fire departments. It is adapted for use at small shop properties or stations where only one average pressure stream of water is available and it may be necessary to vary the size of the stream or even shut it off at the nozzle.

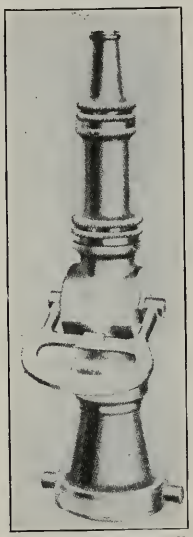


Fig. 5.—Shut-Off Nozzle.

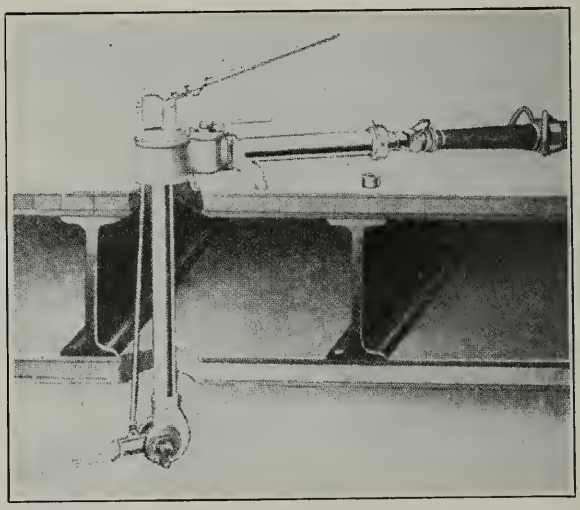


Fig. 6.—Cellar, Roof and Deck Pipe.

Fig. 5 illustrates the Shut-off Nozzle. The name of this type of nozzle suggests its use. Its advantage lies in the saving of excessive water damage when used inside of buildings. It comes in various sizes from one whose butt fits directly onto a 2½-in. coupling or to a standard tip for attachment to the butt of the Underwriters and Boston type play-pipes. It is a very useful nozzle and should be a part of every fire department's equipment.

Fig. 6 shows the Cellar, Roof and Dock Pipe used for fighting fires under floors, under roofs and through partitions or in any blind places that other equipment cannot reach. It may also be turned upside down and used as a small turret play-pipe. It can be turned through a complete circle, and up and down by means of the operating lever at the top. It is provided with a shut-off and is threaded to fit standard 2½-in. fire hose. It is very useful around piers to fight under-floor fires or to get into attics in storehouses, etc.

Fig. 7 shows the Monitor Deluge Type. Nozzles of this type are used to control large streams under high pressure safely. The largest of this type is the fire-boat or

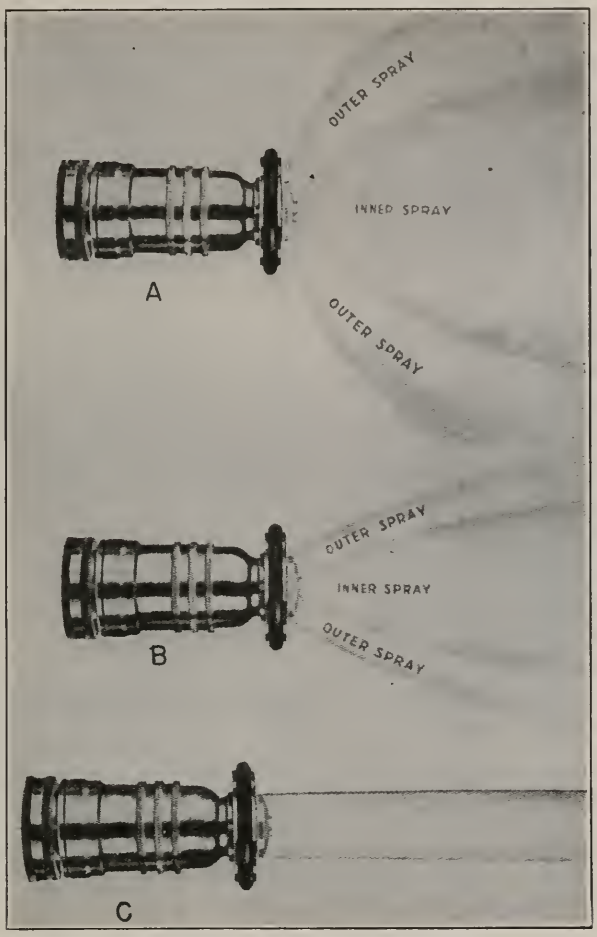


Fig. 8.—Control Type Nozzle.

deck type, which is capable of directing streams discharged through tips with openings from two to six inches. There are various models of this type, for use on walls, ladders, buildings and water towers with various means of control from lever to geared hand wheels. This type of nozzle should be used on tug boats or other boats used for fire protection. It is also useful in tie, timber or coal storage yards.

Fig. 8 shows another control type nozzle tip similar to Fig. 4. It is used for liquid fires and fits as a tip on the Underwriters and Boston play-pipes.

In the last few years the various underwriters' testing laboratories have found that a stream of water broken up into a fog or mist is very effective on oil fires. To gain the best results a high-pressure water stream must be used. It is very important that only the mist or fog be used, because the full stream will splash and spread the burning oil and may do more harm than good.

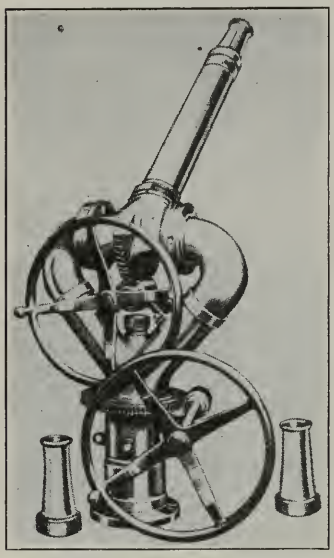


Fig. 7.—Monitor Deluge Nozzle, Fire Boat or Deck Type.

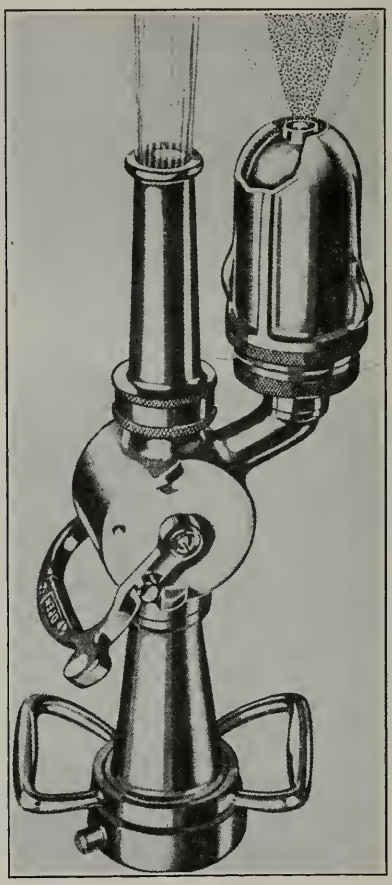


Fig. 9.—Combination Solid Stream and Vapor Nozzle.

In Fig. 8, under A, B and C are diagrams showing the nozzle discharging a double cone of wide mist, a smaller cone for a more direct flow of mist and a direct solid stream of water. The theory of the double cone is that the inner cone penetrates to the fire where it is at once converted into steam, the outer cone retains the steam, forming a blanket over the burning liquid. This nozzle should be used around oil, dope, gasoline and paint storage where high-pressure water lines are available.

Fig. 9 shows a combination for use on small hose streams with the average water pressure. It is useful inside buildings housing flammable liquids, such as are found in dipping tanks, vats and paint-spray outfits. It permits the use of a spray or direct stream on instant notice and has been found very useful in fighting fires inside industrial plants. This type of nozzle should be used on small sized hose located inside of paint shops, oil houses, etc., where it can be used on a fire in its early stages.

Fig. 10 shows the approved water spray nozzle used by the Factory Mutual Laboratories on oil fires such as occur in open oil tanks, and oil-cooled transformers. It has

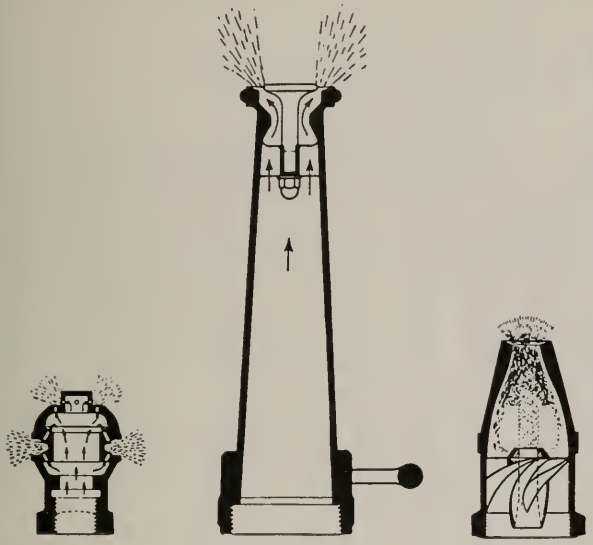


Fig. 10.—Approved Water Spray Nozzles.

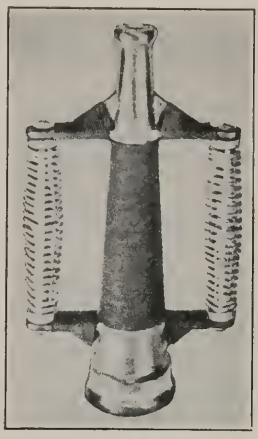


Fig. 11.—Locomotive Type Nozzle.

proved satisfactory in extinguishing oil fires by vapor and mist. This type of nozzle is similar to the one shown in Fig. 8. It is most efficient when used for permanent installations such as at large substations to protect oil-cooled transformers or in large oil and paint storages where the installation is similar to that of a sprinkler system. In the nozzle at the left, in Fig. 10, impinging jets produce a low velocity discharge of fine mist; in the center nozzle, passages of varying diameter result in a disturbed flow which at high velocity produces spray which issues as a hollow cone; in the nozzle at the right, a central solid jet meets a twisting, converging current to produce a solid cone of spray.

Fig. 11 illustrates what is known as the locomotive type nozzle because it is used mostly on locomotives that are equipped with the injector-type fire protection equipment. Its handles are wound with wire and it is designed to be non-static and non-heating to prevent injury from the hot water that comes from an injector branch pipe.

Every pump installed for fire protection purposes is tested in the field by inspectors of the underwriters having jurisdiction in the territory in which it is installed. The usual procedure is to connect 100 ft. of 2½-in. fire hose with an Underwriters play-pipe of 1⅛-in. opening on four different fire hydrants. The hydrants are all opened wide and the pump run to full capacity. Readings are then taken at each nozzle tip with a piezometer gage to determine the capacity of the pump in actual service.

Table 1 shows the data developed by John R. Freeman, and used by underwriters' inspectors, regarding the characteristics of fire streams. It shows the discharge in gallons per minute for six sizes of nozzle tips, the height and distance of each stream for

Table 1 - Fire Streams

From Tables Published by John R. Freeman, M. E.

1-1/8-INCH SMOOTH NOZZLE

Pressure at Nozzle	Gallons Discharged per Min.	Vertical Distance of Stream	Horizontal Distance of Stream	Pressure in pounds required at Hydrant or Pump to maintain pressure at nozzle through various lengths of 2-1/2 inch smooth, rubber-lined hose. 50 Ft.	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	800 Ft.	1000 Ft.
35	222	50	54	43	49	60	71	82	94	105	127	149
40	238	65	59	50	56	69	81	94	107	120	145	171
45	252	70	63	56	63	77	92	106	120	135	163	192
50	266	75	66	62	70	86	102	118	134	150	181	213
55	270	80	69	68	77	95	112	130	147	165	200	235
60	291	83	72	74	84	103	122	141	160	180	218	256
65	303	86	75	81	91	112	132	153	174	195	236	...
70	314	88	77	87	98	120	143	165	187	209	254	...
75	325	90	79	93	105	129	153	177	201	224	...	...
80	336	92	81	99	112	138	163	188	214	239	...	...
85	346	94	83	106	119	146	173	200	227	254	...	...
90	356	96	85	112	126	155	183	212	241	...	...	...
95	366	98	87	118	133	163	194	224	254	...	...	...
100	376	99	89	124	140	172	204	236	...	...	...	...

1-1/4-INCH SMOOTH NOZZLE

35	277	60	59	48	57	74	91	109	126	142	178	212
40	296	67	63	55	65	84	104	124	144	164	203	243
45	314	72	67	62	75	95	117	140	162	184	229	...
50	331	77	70	68	81	106	130	155	180	204	254	...
55	347	81	73	75	89	116	143	170	198	225	...	...
60	363	85	76	82	97	127	156	186	216	245	...	...
65	377	88	79	89	105	137	169	201	234	...	...	...
70	392	91	81	96	113	148	182	217	252	...	...	...
75	405	93	83	103	121	158	195	232	...	...	...	...
80	419	95	85	110	129	169	208	248	...	...	...	...
85	432	97	88	116	137	179	221	...	...	...	...	...
90	444	99	90	123	145	190	234	...	...	...	...	...
95	456	100	92	130	154	201	247	...	...	...	...	...
100	468	101	93	137	162	211	261	...	...	...	...	...

1-3/8-INCH SMOOTH NOZZLE

35	340	62	62	54	67	94	110	146	172	198	250	...
40	363	69	66	62	77	107	137	166	196	226	...	...
45	385	74	70	70	87	120	154	187	221	454	...	...
50	406	79	73	78	96	134	171	208	245	...	...	...
55	426	83	76	86	106	147	188	220	270	...	...	...
60	445	87	79	93	116	160	205	250	...	...	...	...
65	463	90	82	101	125	174	222	...	...	...	...	...
70	480	92	84	109	135	187	239	...	...	...	...	...
75	497	95	86	117	145	201	256	...	...	...	...	...
80	514	97	88	124	154	214	...	...	...	...	...	...
85	529	99	90	132	164	227	...	...	...	...	...	...
90	545	100	92	140	173	240	...	...	...	...	...	...
95	560	101	94	148	183	254	...	...	...	...	...	...
100	574	103	96	156	193	...	...	...	...	...	...	...

Table 1 - Fire Streams

From Tables Published by John R. Freeman, M. E.

3/4-INCH SMOOTH NOZZLE

Pressure at Nozzle	Gallons Discharged per Min.	Vertical Distance of Stream	Horizontal Distance of Stream	Pressure in pounds required at Hydrant or Pump to maintain pressure at nozzle through various lengths of 2-1/2 inch smooth, rubber-lined hose.								
				50 Ft.	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	800 Ft.	1000 Ft.
35	97	55	41	37	38	40	42	44	46	48	53	57
40	104	60	44	42	43	46	48	50	53	55	60	65
45	110	64	47	47	48	51	54	57	59	62	68	75
50	116	67	50	52	54	57	60	63	66	69	75	81
55	122	70	52	58	59	63	66	69	73	76	83	89
60	127	72	54	63	65	68	72	76	69	83	90	97
65	132	74	56	68	70	74	78	82	86	90	98	106
70	137	76	58	73	75	80	84	88	92	97	105	114
75	142	78	60	79	81	85	90	94	99	104	113	122
80	147	79	62	81	86	91	96	101	108	111	120	130
85	151	80	64	89	92	97	102	107	112	117	128	138
90	156	81	65	94	97	102	108	113	119	124	135	146
95	160	82	66	99	102	108	114	120	125	131	143	154
100	164	83	68	105	106	114	120	126	132	138	150	163

7/8-INCH SMOOTH NOZZLE

35	133	56	46	33	40	44	48	52	56	60	68	76
40	142	62	49	45	46	50	55	59	64	68	78	87
45	150	67	52	49	51	57	62	67	72	77	87	97
50	159	71	55	54	57	63	69	74	80	86	97	108
55	166	74	58	60	63	69	75	82	88	94	107	119
60	174	77	61	65	69	75	82	89	96	103	116	130
65	181	79	64	71	74	82	89	96	104	111	126	141
70	188	81	66	76	80	88	96	104	112	120	136	152
75	194	83	68	82	86	94	103	111	120	128	145	162
80	201	85	70	87	91	101	110	119	128	137	155	173
85	207	87	72	92	97	107	116	126	136	145	165	184
90	213	88	74	98	103	113	123	134	144	154	174	195
95	219	89	75	103	109	119	130	141	152	163	184	206
100	224	90	76	109	114	126	137	148	160	171	194	216

1-INCH SMOOTH NOZZLE

35	174	58	51	40	44	51	57	64	71	78	92	105
40	186	64	55	46	50	58	66	73	81	89	105	120
45	198	69	58	52	56	65	74	83	91	100	118	135
50	208	73	61	57	62	72	82	92	102	111	131	151
55	218	76	64	63	69	79	90	101	112	122	144	166
60	228	79	67	67	75	87	98	110	122	134	157	181
65	237	82	70	75	81	94	107	119	132	145	170	196
70	246	85	72	80	87	101	115	128	142	156	183	211
75	255	87	74	86	94	110	123	138	152	167	196	226
80	263	89	76	92	100	115	131	147	162	178	209	241
85	274	91	78	98	106	123	139	156	173	189	222	...
90	279	92	80	103	112	130	147	165	183	200	236	...
95	287	94	82	109	118	137	156	174	193	211	249	...
100	295	96	83	115	125	144	164	183	203	223	...	...

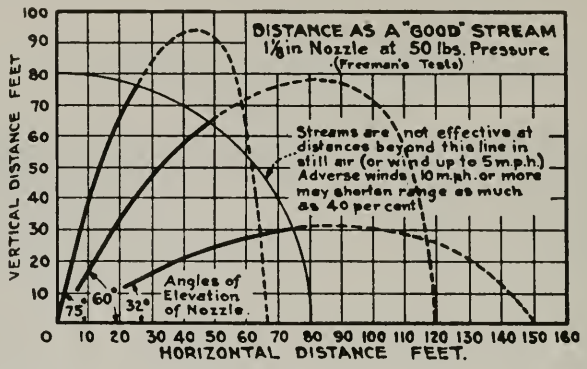

DISTANCE AS A "GOOD" STREAM
1⅛in Nozzle at 50 lbs. Pressure
(Freeman's Tests)
Streams are not effective at distances beyond this line in still air (or wind up to 5 m.p.h.) Adverse winds 10 m.ph. or more may shorten range as much as 40 per cent
Angles of Elevation of Nozzle.
75°
60°
32°
VERTICAL DISTANCE FEET
HORIZONTAL DISTANCE FEET.
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
10 20 30 40 50 60 70 80 90 100

FIG. 12.—Effective "Good Stream" Distance for Discharging from 1⅛-in. Nozzle at 50 lb. Pressure.

various lengths of hose, and the pump pressure necessary to maintain the required pressure at the nozzle tip. A portion of these data, as applied to a 1⅛-in. nozzle at 50-lb. pressure is shown graphically in Fig. 12.

This report is submitted as information.

Appendix E

(7) TRUCKS FOR USE BY WATER SERVICE MAINTENANCE FORCES

Collaborating With Committee 27—Maintenance of Way Work Equipment

J. P. Hanley, Chairman, Subcommittee; H. M. Hoffmeister, H. F. King, C. R. Knowles, G. F. Metzdorf, L. B. Paine, W. G. Powrie, D. A. Steel, J. E. Tiedt.

The use of commercial trucks by the maintenance of way departments of railways, including water service work, has attained considerable proportions and will probably increase. In congested districts and terminals the use of trucks has been found preferable to rail motor car or train transportation for tools and material, as the latter method causes annoyance to revenue passengers when trains are used, and interference with traffic when the use of motor or push cars is attempted. In less congested and even sparsely settled districts, the use of rail motor cars usually involves more than one man to handle the car and its load, and the use of trains is not satisfactory owing to the decrease in the number of local trains and the delay and expense involved in stopping manifest trains at local points.

In the Chicago terminal area of one railway, 12 trucks are used by the maintenance of way department. The trucks are operated and maintained by the division foreman of water service and deliver the lighter materials and equipment required by the division track, water service, and building departments, which were formerly handled on suburban trains. The trucks are found to be more flexible and economical for prompt handling of material to the work. The Waterloo, Iowa, Memphis, Tenn., New Orleans, La., and other terminals of this railway are also provided with trucks which render a similar community service to the division subdepartments, including water service.

The use of light trucks for water service men exclusively is not so well established, but the railway mentioned has two men so provided. Local train service is not available on the districts maintained by these men, but the trucks enable them to reach the most isolated station on the district and return to headquarters with a minimum amount of travel time.

A questionnaire was sent to members of Committee 13 to secure information on the extent to which trucks are used by their respective railways for water service work and a summary of the information received is shown in the table.

Use of Trucks by Water Service Forces

Railway	*No. of Trucks used by:* *M. of W.*	*Water Service*	*Truck capacity Tons*
Ann Arbor	0	Water service men use private autos	
C. & O.	4	0	1½
A. T. & S. Fe.	8	2	½ to 2
C. & N. W.	7	2	1½
C. M. St. P. & P. (B&B)	6	1 auto	½ to 2
C. R. I. & P.	9	8	½
Erie	15	0	¾ to 2½
D. & R. G. W.	3	0	1
D. L. & W.		4	½
G. N.	71	3	½ to 1½
I. C.	20	2	½ to 1½
N. P.	5	1	½
M. K. T.	1	0	1½
N. Y. C. (West)	3	2	1½
T. & P.	1	2	½
		1 auto	
N. Y. C. & St. L. (B&B)	1	1 Part time	1½

Note: The replies received stated that the use of trucks was very satisfactory.

In considering this subject, it should be understood that many water service men use their own automobiles extensively in their work and that the maintenance of way department trucks provide community service for subdepartments in which water service men share to a considerable extent.

The capacity of trucks used by maintenance of way departments varies from ½ to 2½ tons. The smaller size is preferred for water service men and for light maintenance trucking. The open body is generally satisfactory but canopy and stake bodies can be secured without much extra cost. The driver's seat should be enclosed for all-weather use. Bodies having racks for the convenient storage of fittings, and small hoists actuated by the truck motor should be considered in special cases.

The approximate price and operating costs for ½-ton trucks suitable for water service men follow:

Cost—½-ton truck, open body—standard equipment, $655.

Annual cost of operation.

5 percent interest on cost, $655	$ 32.75
20 percent depreciation	131.00
Maintenance	60.00
Insurance (personal liability, property, fire & theft)	60.00
License—state and city	20.00
Gasoline—800 gal. at 18 cents	144.00
Lubricants	40.00
	$487.75

Mileage—12,000 miles per year
Average cost per mile.....four cents.

The first cost and the operating cost of light trucks for water service men is not unreasonable and it is believed the trucks are justified in certain cases where local train or rail motor car service is not adequate or where the water service man does not use his own automobile or secure service from some other departments.

The Railway Age of October 5 and October 12, 1929, published an article entitled "The automobile goes to work for the Great Northern Railway." This article states that the railway had acquired over 60 company-owned automobiles and highway trucks at an investment of approximately $100,000, to assist the stores, maintenance of way, and mechanical departments in their work. The equipment was used for carting men and material, policing telephone lines, and for numerous kinds of routine and emergency shipments of company material. It was roughly estimated that the equipment saved its cost every year in this work.

Another article appearing in the same publication on October 6, 1932, entitled "A National Survey of Company-Owned Automobiles and Trucks for Non-Revenue Work" indicates the following units in use by all American railways at that time:

	Roadway Department	*Total*
Passenger autos	123	392
Highway trucks	274	1070
Motor busses	6	61

The latter article also shows in detail the number of tractors, trailers, cranes and similar equipment by categories and by individual railways. Both articles give useful information for those interested in motorized equipment.

Conclusions

The use of trucks for water service men is justified for the following reasons:

1. Saves time in getting to the job because the equipment is promptly available day or night.

2. Greater safety on the roadway where flagging, meeting and passing regulations are not complicated.

3. Greater economy in handling as compared with a work train or heavy rail motor car, including the load.

4. Greater tool and material-carrying capacity than light rail motor cars or speeders.

5. Decreased cost in overhead and operating expense, compared with work-train or switching service.

6. Economy in drayage cost as against similar work by contract truckers.

7. Railways are taxed for highway purposes and the maximum use of highways for railway equipment is not inconsistent.

This report is submitted as information.

Appendix F

(9) METHODS FOR CHECKING AND HANDLING THE CONTROL OF LOCOMOTIVE BLOWDOWNS

J. B. Wesley, Chairman, Subcommittee; R. E. Coughlan, E. M. Grime, J. S. Hancock, R. L. Holmes, H. F. King, C. R. Knowles, H. M. Laudemann, M. E. McDonnell, H. L. McMullin, A. B. Pierce, H. W. Van Hovenberg.

A report submitted by this committee and published in Vol. 37 of the Proceedings of the Association gives an extended discussion of Boiler Water Conditions Affecting the Extension of Locomotive Washout Periods. That report also included a discussion of general boiler blowing, the objections to blowing boilers, and the benefits to be derived from blowing them. It is the purpose of this report to give more detailed consideration to the control of boiler blowing and to the facilities provided to make it possible to blow them wherever and whenever the engineman considers blowing to be needed or desirable. To secure successful and satisfactory boiler blowing, it is necessary to have close supervision at each terminal; convenient blow-off cocks must be provided; safe and satisfactory means for disposing of the discharge from the boiler must be arranged, both at the terminal and on the road, and instructions to serve as a guide for the blowing to be done by the enginemen must be set up.

Supervision

The water chemist is the most important unit in the supervisory organization. He is the one who must analyze the different waters used in the locomotive boilers, he must determine what water supplies are most likely to cause foaming trouble and what waters can be used with the least boiler blowing. He must determine what concentration is satisfactory to have in the boiler when the engine leaves the terminal and what is the "critical point" of concentration at which foaming will be likely to take place. So far as the water is concerned, these departure concentrations and "critical point" concentrations vary with the type of mineral salts in the water used, and each road should make these determinations for its own waters. When these two essential points have been established, it then becomes necessary to test water samples taken from boilers before departure from the terminal to insure that the concentration is within proper limits. Samples should be tested on arrival at terminal to see that blowing on line has been sufficient to keep the concentration in the boiler below the "critical point" and that excessive blowing, which is wasteful of fuel, water and chemicals, has not been done.

Taking Water Samples from Boilers

Care should be taken to insure that the water sample tested is representative of the water in the boiler. Since there is rapid circulation over the boiler backhead onto the crown sheet, water taken from the water column drain, after the column has been thoroughly blown down, or from one of the gage cocks, will probably be as representative as can be secured. The collecting vessel should be clean and no pollution of the sample should be permitted. When water is drawn from under pressure within the boiler to the atmospheric pressure outside, a portion of the superheated water will immediately flash into steam. The remaining water will then contain its original amount of dissolved solids plus what was in the water that flashed into steam; so the test obtained from the sample collected will show a concentration somewhat higher than that actually existing inside the boiler. However, since this flash factor is common to all the tests made and the relative conditions are practically constant, this flash into steam can be disregarded and the determinations as made can be used for controlling the boiler blowing.

Testing Boiler Samples

There is only one way to make an exact determination of the amount of mineral substance dissolved in a sample of water. This is by evaporating a measured quantity of the water in a weighed container, weighing the container and residue after they are cooled to room temperature, and the difference between the two weights is the amount of substance contained in the water. This determination requires a delicate balance, a skilled operator, and considerable time: so it does not meet the requirements for checking water at terminals. It is necessary that some degree of accuracy in the determination be sacrificed in order to meet the requirements of simplicity and reasonable haste. Two types of instruments that meet these requirements in railroad work have been developed. These are:—(a) Specific gravity measurement and (b) electric conductivity measurement.

(a) Specific Gravity Test

A number of instruments making use of the specific gravity measurement have been developed and are in general use. Most of them are of the hydrometer nature, but in addition to the regular hydrometer scale they carry a thermometer with a second scale from which corrections for temperature variations are made. These hydrometers vary principally in their scale calibrations. For instance, one make is calibrated to read directly in grains per gallon, another type to read in degrees Baumé, which in turn can be converted to grains per gallon by the use of a conversion factor, and on a third type the scales are calibrated to read numbers only, which when multiplied by the conversion factor give results in grains per gallon. There is also an instrument using the specific gravity principle that is not of the hydrometer type. This instrument consists of two parts, a small glass float and a thermometer that is calibrated to read in terms of grains per gallon. The float and thermometer are both placed in the water sample while the temperature is high enough for the float to sink. The sample is permitted to cool slowly until the float rises to the top, at which time the thermometer is read. There is no temperature correction to be made.

In general, the hydrometer jar or cylinder should stand vertical and be of sufficient diameter that the float will be free of the sides. The water should be at the room temperature, and the float should remain in the sample approximately two minutes before the readings are made. With the small two-part instrument the water sample must be warm enough for the float to sink. If it remains on top, the sample must be heated.

The hydrometer instruments are too large to carry about conveniently but they have an advantage in not requiring a definite temperature at which readings have to be made. The two-piece instruments are small and can be carried in a pocket; so they are particularly suited for use by traveling inspectors.

(b) Electric Conductivity Measurement

This instrument makes use of the fact that as the amount of dissolved substance increases, the electric conductivity of the solution increases. Although the ratio is not constant, this is compensated for in the calibration of the instrument. Also, there is an adjustment for automatic temperature correction, so that the reading of the scale is direct in terms of grains per gallon. The instruments are made for both alternating and direct current.

Like all scientific instruments, these must be kept clean and all work with them must be done conscientiously. These instruments are relatively heavy and bulky, not suitable for portable outfits, but are particularly suited for terminal use.

It is not the province of this report to attempt to set up the relative accuracy of these different instruments. It is enough to say that: (1) each of them must be *kept clean* if their determinations are to be reliable, (2) each of them must be calibrated against gravimetric determinations at intervals to assure their correctness, and (3) the operator at the terminal must have an interest in securing the most accurate determinations possible. With these conditions existing, it is possible to provide satisfactory control and supervision of conditioning water in the boiler by blowing.

Boiler Blow-off Valves

Foaming is primarily caused by the accumulation of mud (or sludge) and the concentration of alkaline mineral salts contained in the water within the boiler. Each time the blow-off valve is opened, a portion of these substances is blown out. If enough blowing is done, there will be no accumulation or concentration sufficient to cause foaming, and foaming will not take place. Since the rate of accumulation in the boiler depends on the characteristics of the water supplies used and on the rate at which the water is evaporated, both variable features, it is quite evident that the blow-off facilities provided must be flexible enough to meet these varying conditions. Numerous attempts to construct blow-off facilities to accomplish this have been made, most of them having merit, but none of them has met all conditions satisfactorily.

Continuous blow-off arrangements have been made, with both automatic and manual control. A nipple with a restricted orifice is set in the discharge line to regulate or control the rate of discharge from the boiler. They permit no variation to compensate for variable water supplies, different loads, or different weather conditions. This feature is characteristic of practically all automatic and all continuous boiler blowing facilities. The one exception to this generality is an electrically operated apparatus. Power is taken from the locomotive generator. When foam builds up in the boiler sufficiently high to close the circuit between two electrodes suspended in the steam space, the blow-off valve opens. It remains open until the foam falls away and the electric circuit is broken, at which time the valve closes. This apparatus constitutes at present the nearest approach to a completely satisfactory automatic boiler blowing appliance. Its greatest deficiency apparently lies in the fact that on an engine operating in "hogback" territory, the apparatus tends not to function on downgrade movement, but does function on uphill movement when steam and water demands are greatest. It cannot anticipate a heavy steam demand and condition the water in the boiler in advance.

There are many of these various devices in use on locomotives and within their limitations are giving satisfaction. But the fact remains that the engineman must be provided with a manual blow-off cock by which he can at will and need supplement the continuous or automatic blowing to prevent or cure foaming trouble.

Disposal of Discharge from Blow-off Valves

(a) At Terminals.—When boilers are given terminal blowing, those equipped with mufflers are usually blown into the cinder pit, and no blow-down box is required. For handling engines not equipped with mufflers some suitable arrangement must be made for disposing of the water blown out. If it is desired to recover the blow-down, water toggles are installed to provide connection between the blow-off valve and the boiler washing plant. Otherwise, blow-down boxes, either wood or steel, are erected with a side opening next the track, a hole in the top for steam escapement and the bottom drained to the sewer for the water. Sometimes it is necessary to build baffle boards along the inside walls of the boxes to prevent the water from being blown out of the top along with the steam.

(b) On Road.—In the sections of the country where the population is heavy and structures are numerous and near the track it has been found necessary to equip the blow-off facilities with mufflers to prevent the water blown out from damaging structures and injuring men and animals. Mufflers are of two general types. In one type the boiler discharge is forced through a box or cylinder provided with a series of baffles or perforated plates. The water from the boiler in passing through these mufflers is broken up into a spray having low pressure. This spray can be discharged onto the roadbed without damage to the track, structures along line or hazard to men. These mufflers are usually located beneath the cab or cab deck and discharge either between the rails or on the ends of the ties outside the rail. They are made in various shapes and dimensions, conforming to the ideas of the local officers.

The second type of muffler functions on the principle of a centrifuge. The discharge from the boiler is received into a round box at such an angle that a rapid circular motion is set up. The light steam remains near the center of the box and escapes to the atmosphere through a hole in the top. The water, being heavier, is thrown against the walls and drains out through a hole in the bottom. A pipe receives this drainage and conducts it to an open discharge near the track. The discharge opening should be set so that the water falls downward and out at such an angle as to hit the ground on the track shoulder beyond the ballast. The round box, or separator, is located on top of the boiler in front of the cab where the escaping steam does not obscure the ordinary vision of the train and enginemen. The centrifugal type muffler accomplishes all that the baffle or perforated plate type does, and, in addition, it disposes of the discharge in such a way as to give a more open and clearer visibility. However, both types are used extensively, permitting safe boiler blowing at any place at any time.

Instructions for Blowing

As noted in a previous paragraph dealing with blow-off valves, the amount of blowing required to be done on the line is not a fixed or set quantity. The qualities of the waters used on one operating district are different from the waters used on some other district, and if the water supplies are taken from streams, the quality at the individual station will vary with changes in the stage of the stream and from season to season. No two operating districts have waters of the same qualities and the same amount of blowing will not meet the water requirements of any two districts. Further, the amount of blowing is also affected by the rate of evaporation in the boiler, which in turn is controlled by a number of variable causes, such as the speed of the train, the load being handled, the weather conditions, and the season of the year. It is safe to say that not only will no two districts have the same blowing requirements, but it is extremely doubtful if any two trains on the same district will require the same amount of blowing from day to day. It is for this reason that a detailed schedule for blowing cannot reasonably be set up to cover operation over an entire system or even for an operating district. The best that can be done is to set up a "minimum blow" schedule, such as will keep the mud and sludge drafted out, this blowing to be done even though no foaming occurs.

The total amount of blowing to be done to prevent foaming must rest with the engineer. He operates over his district under all the varying conditions of load, speed, weather, and season, and by experience learns the amount of blowing to do. If foaming occurs, the amount of blowing is insufficient; if foaming does not occur the blowing is sufficient. Excessive blowing can be determined by checking the inbound test records at terminals.

The following is quoted from the "Blowing Instructions" issued by one railroad.

"Road Locomotives

"Enginemen and firemen must open each blow-off cock at least three times during each 20-mile run. Each time blow-off cock is opened, it must remain open at least five seconds. Each time it is closed it must remain closed three seconds or more before opening next time.

"Additional Blowing

"Amount of blowing by enginemen and firemen, prescribed above is minimum required in all territories." . . . "Engine crews on extended locomotive runs must blow boilers enroute sufficiently to prevent T.D.S. exceeding 150 grains on arrival at terminal."

Another road says,—"On line of road on the ..... divisions, the blow-off cock must be opened not less than six times of five seconds duration each hour . . .", and adds,—"This is the minimum blowing to be done and additional blowing must be done when required to prevent boilers foaming".

Under such instructions, the engineman is not restricted in his use of the blow-off cock but is permitted free exercise of his judgment to meet the varying conditions as they arise.

To assist enginemen in blowing most effectively, they should be instructed to blow for short periods only, possibly five seconds at a time, and to alternate from right to left. If long blowing is necessary the injector or water pump should be shut off while the blow-off valve is open. If both cocks discharge through a common muffler only one cock should be open at a time. If both are opened at the same time and one fails to close, there is no way to tell which is at fault and an engine failure may occur. However, on those roads that provide a second valve, manually operated, with each blow-off cock, boilers can be safely blown from both sides at the same time.

Conclusions

Routine checks of water taken from boilers should be made at all principal terminals. Any one of a number of instruments available for this work is satisfactory, provided they are kept clean, they are calibrated at intervals, and those who use them are careful in their work.

Blow-off valves of sufficient capacity and convenient for operation should be provided.

Suitable blow-down boxes or other facilities for disposing of boiler waste should be provided at terminals.

Mufflers that will dispose of the water discharged from the boiler so as to prevent damage to track and structures or injury to men and animals should be provided.

Instructions issued to enginemen with regards to blowing boilers should be sufficiently flexible to permit them free exercise of their judgment in blowing to meet the variable conditions under which they operate.

This report is submitted as information.

A

REPORT OF COMMITTEE 14—YARDS AND TERMINALS

Hadley Baldwin, *Chairman;*
J. R. W. Ambrose,
C. E. Armstrong,
J. E. Armstrong,
C. J. Astrue,
H. G. Basquin,
E. J. Beugler,
W. O. Boessneck,
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H. F. Burch,
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R. B. Elsworth,
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E. D. Gordon,
J. L. Gressit,
R. J. Hammond,
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M. J. J. Harrison,
E. M. Hastings,
W. J. Hedley,
H. O. Hem,
W. H. Hobbs,
J. M. Hood,
A. B. Jacobus.
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L. L. Lyford,
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C. A. Mitchell,
W. F. Cummings, *Vice-Chairman;*
C. H. Mottier,
H. C. Propst,
T. R. Ratcliff,
C. L. Richard,
H. L. Ripley,
H. M. Roeser,
W. B. Rudd,
W. C. Sadler,
C. U. Smith,
E. E. R. Tratman,
H. L. Vandament,
E. P. Vroome,
W. J. Yearsley,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Arrangement of tracks and facilities for passenger stations and engine terminals required to meet the demands of internal combustion and electric locomotives. Progress in study—no report.

3. Auxiliary yard facilities and appurtenances. Progress in study—no report.

4. Scales used in railway service (Appendix B). Recommended for publication in the Manual in substitution for corresponding material now appearing therein.

5. Bibliography on subjects pertaining to yards and terminals appearing in current periodicals (Appendix C). Progress report.

6. Substitution of outlying yards and facilities for yards and other large facilities in cities where land values are high (Appendix D). Progress report.

7. Classification Yards, collaborating with Committee 16—Economics of Railway Location and Operation (Appendix E). Progress report.

8. Adaptation of enginehouses, shops and engine terminal layouts for handling oil-electric locomotives and rail cars. Progress in study—no report.

The Committee on Yards and Terminals,
Hadley Baldwin, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

L. L. Lyford, Chairman, Subcommittee; Hadley Baldwin, W. F. Cummings, F. T. Darrow, W. H. Giles, G. F. Hand, M. J. J. Harrison, E. E. R. Tratman.

The following revisions in Section 2411, page 14–11, entitled "Elevators and Escalators" are recommended:

Title—Substitute "Moving Stairways" for the word "Escalators" so that it will read "Elevators and Moving Stairways."

Paragraph (b)—Delete the words "or escalators" so that it will read—"For heights less than 25 feet under normal conditions, passenger elevators are not recommended as

approaches to individual passenger platforms. They may be desirable as a supplement to stairs for the use of the aged and infirm."

Paragraph (d)—Delete the word "escalator" and substitute the words "moving stairways," so it will read "A single elevator or moving stairway should not be relied upon as the sole means of approach to a station platform."

Paragraph (e)—Insert the words "Moving stairways or" before the word "Escalators" at the beginning of the first sentence and delete the second sentence, substituting the following: "They are being used successfully in both suburban and through passenger service.", so that the paragraph will read "Moving stairways or escalators have a carrying capacity of approximately 33 passengers per foot of width per minute. They are being used successfully in both suburban and through passenger service."

Appendix B

(4) SCALES USED IN RAILWAY SERVICE

M. J. J. Harrison, Chairman, Subcommittee; John E. Armstrong, Hadley Baldwin, H. G. Basquin, W. J. Brennen, E. D. Gordon, E. M. Hastings, H. O. Hem, A. B. Jacobus, E. K. Lawrence, H. C. Propst, C. L. Richard, H. M. Roeser, W. C. Sadler, C. U. Smith, E. P. Vroome.

Under this heading, your committee submits proposed revisions of two sections of Chapter 14 of the Manual.

(1) At the 1927 convention (Vol. 28, 1927 Proc., pages 592 and 1409), there was presented and adopted a set of specifications for the manufacture and installation of two-section, knife-edge railway track scales. Experience in the application of these specifications suggested certain desirable revisions. Accordingly, at the 1937 convention (Vol. 38, 1937 Proc., pages 67 and 594), there was presented and received as information a new specification under the same title as that of the 1927 material. It was then contemplated that the specifications submitted as information in 1937 would be submitted to the 1938 convention under the heading "Revision of Manual". Such, however, was found to be impracticable, and due note to that effect was made a part of the 1938 report of your committee (Vol. 39, 1938 Proc., pages 232 and 775).

The material submitted as information in 1937 has now been critically reviewed, revised somewhat, and agreed to by your committee. It differs from present Manual material chiefly in editorial arrangement, and to some extent in technical detail. Its adoption by the Association under the title "Specifications for the Manufacture and Installation of Two-Section, Knife-Edge Railway Track Scales—1939", and as a substitute for material now appearing under a corresponding title on pages 14–67 to 14–83, inclusive of the Manual, is recommended.

(2) Experience in the application of the "Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-contained and Portable Scales for Railway Service—1936", and the requests made on the committee for interpretations, have suggested three desirable revisions of as many items thereof. The proposed revisions are shown in detail herein, and their approval by the Association is recommended.

53. SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF TWO-SECTION, KNIFE-EDGE RAILWAY TRACK SCALES

1939

INTRODUCTION

These specifications are intended to apply to two-section, knife-edge railway track scales without dead rails or relieving gear, but not overhead suspended scales nor scales already in service, except that reinstallation of old scales should conform to the provisions relating to installation and to pivot and bearing steels.

Requests for proposals should specify sectional capacity and length of scale required, together with such other information as will result in complete and uniform proposals.

53—I CAPACITY

101. Sectional Capacity Defined

The sectional capacity of a scale is the greatest live load which may be divided equally on the load pivots of a section without producing in any member stresses in excess of those specified in Section 53—III.

102. Sectional Capacities Standardized

The rated sectional capacity of a two-section, knife-edge railway track scale shall be either 150 or 200 tons. The rated sectional capacity shall not exceed the actual sectional capacity as defined in Article 53—101.

103. Scale Capacity Defined

The capacity of a two-section railway track scale is the weight of the heaviest locomotive that may pass over it without developing in any member stresses in excess of those specified in Section 53—III.

104. Nominal Capacity Defined and Limited

The nominal capacity of a scale is the largest weight indication that can be obtained by the use of all the reading elements in combination, fractional bars totaling 2 percent or less of the remaining elements being neglected. The nominal capacity of a two-section track scale shall not exceed the rated sectional capacity.

53—II PLANS

201. Plans to be Furnished

Assembly plans shall be furnished showing the location of field connections and all information necessary for the purchaser to design and construct the pit and parts not furnished by the manufacturer. On request, the manufacturer shall furnish to the purchaser plans showing materials, stresses, and detailed dimensions for all scale parts.

53—III WORKING STRESSES AND FORMULAS

301. Unit Stresses

For all materials covered by specific mention in this Section, the unit stress given in this Article contains sufficient provision for impact.

In designing cast iron members to sustain stress of any character, the maximal allowable unit stress shall be determined by the greatest thickness, exclusive of fillets, of the portion of the section carrying the stress being considered. In the main portion of a

beam, the thickness of the web or flange shall be used, whichever is the greater. The thickness of the flange shall be considered either as the average depth of the outstanding portion, or the breadth of flange outside to outside, whichever is less.

TABLE 1414

ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH FOR IRON AND STEEL

Material	*Transverse Bending*		*Direct Stress*		*Shear and*
	Tension	*Compression*	*Tension*	*Compression*	*Tension*
Cast Iron (gray), Thickness of section *Inches*					
0.25	5,000	8,500	3,500	10,000	5,000
0.3	4,780	8,130	3,350	9,560	4,780
0.35	4,600	7,820	3,220	9,200	4,600
0.4	4,450	7,560	3,110	8,900	4,450
0.45	4,320	7,340	3,020	8,640	4,320
0.5	4,200	7,140	2,940	8,400	4,200
0.6	4,020	6,830	2,810	8,040	4,020
0.7	3,870	6,580	2,710	7,740	3,870
0.8	3,740	6,360	2,620	7,480	3,740
0.9	3,630	6,170	2,540	7,260	3,630
1.0	3,540	6,020	2,480	7,080	3,540
1.1	3,450	5,860	2,410	6,900	3,450
1.2	3,380	5,750	2,370	6,760	3,380
1.3	3,310	5,620	2,320	6,620	3,310
1.4	3,250	5,520	2,270	6,500	3,250
1.5	3,190	5,420	2,230	6,380	3,190
1.6	3,140	5,340	2,200	6,280	3,140
1.8	3,050	5,180	2,130	6,100	3,050
2.0	2,970	5,050	2,080	5,940	2,970
2.5	2,810	4,780	1,970	5,620	2,810
3.0	2,690	4,570	1,880	5,380	2,690
3.5	2,580	4,390	1,810	5,160	2,580
4.0	2,500	4,250	1,750	5,000	2,500
Steel					
Castings	10,000	12,000	10,000	12,000	8,000
Pivots and Bearings—					
S.A.E. 6,195 or 52,100, hardened	30,000	30,000	30,000	30,000	
Structural—					
S.A.E. 1,010 to 1,020	10,000	10,000	10,000	10,000	6,000
Stress in extreme fibers of pins					15,000
Shear in power-driven rivets and pins					7,500
Shear in turned bolts and hand-driven rivets					6,000
Bearing on pins					14,000
Bearing on power-driven rivets, milled stiffeners, and other parts in contact					15,000
Bearing on rocker pins					7,000
Bearing on turned bolts and hand-driven rivets					11,000

Rivets driven by pneumatically or electrically operated hammers are considered power-driven.

For countersunk rivets, the above values shall be reduced 25 percent. Countersunk rivets shall not be assumed to carry bearing stress in metal less than ⅜ inch thick.

In proportioning rivets, nominal diameters shall be used.

The effective bearing area of a pin, bolt or rivet is the nominal diameter multiplied by the thickness of the metal upon which the member bears.

The gross area of the compression flange of a structural member shall be not less than the gross area of its tension flange.

302. High Strength Alloys

For materials intended or represented to be "high strength" alloys, unit working stresses other than those given in Table 1414 may be used, provided these do not exceed 1/3 the unit stress at the yield point established according to the test routine followed or prescribed by the American Society for Testing Materials for parts of the same analysis, heat treatment, and size, and provided further that the unit working stresses for any combination of gray iron and carbon steel exclusively shall not exceed those given in Table 1414 for steel castings. The purchaser, if he requests, shall be furnished with sufficient data or test specimens to enable him to determine the physical properties of the particular "high strength" material proposed to be used.

303. Knife-Edge Bearing Stress

The load per inch of knife-edge shall not exceed 6,000 pounds.

304. Concrete Bearing Stresses

Bearing stress on concrete shall not exceed 300 pounds per square inch under scale lever stands, and 400 pounds per square inch at all other points.

305. Projecting Pivots—Formula for Stresses

Where practicable, pivots shall be supported their full length by integral parts of the containing lever. Where impracticable so to support the pivots, external bending moments shall be determined as follows:

Let $M =$ the required bending moment in inch-pounds
$L =$ the length in inches of the moment arm
$T =$ the distance in inches between the friction faces of the loop
$W =$ the total load in pounds on both ends of the pivot
$D =$ the length in inches of bearing in the loop
$B =$ the width in inches of the boss, or sustaining member enveloping the pivot
Then $L = D/2 + (T - B) + \frac{1}{4}$ inch
and $M = WL/2$

306. Levers—Formulas for Loading

The main levers in a section shall be assumed to carry the sectional capacity equally divided between them. Each end extension lever shall be assumed to carry a load corresponding to 100 percent of the sectional capacity. The transverse extension lever, shelf lever, and weighbeam shall be assumed to carry a load corresponding to 200 percent of the sectional capacity.

307. Bearing Pressures Under Foundations

The bearing areas of foundation footings shall be such that the pressure under the footings will not exceed,

For fine sand and clay	4,000 lb. per sq. ft.
For coarse sand and gravel, or hard clay	6,000 lb. per sq. ft.
For boulders or solid rock	20,000 lb. per sq. ft.

If the soil has not a safe bearing capacity equal to that of fine sand or clay, its bearing capacity shall be increased by drainage, by adding a layer of gravel or broken stone, or by driving piles.

53—IV LENGTH OF SCALE

401. Scale Length Defined

The length of a scale is the length of its weigh rails.

402. Scale Lengths—Limits

For general railway service the minimal scale length shall be 50 feet. For scales of 150 tons sectional capacity, the length shall not exceed 60 feet.

403. Limits of Overhang

The scale may be longer than the distance between its sections. In no case, however, shall the distance from the center of a section to the nearer end of the weigh rails exceed 3 feet.

53—V SCALE LEVERS

501. Qualities of Castings

Castings used for levers shall not be warped. They shall be clean, smooth, uniform, and free from blisters, blowholes, and shrinkage holes and cracks.

502. Machined Ways for Nose Irons

Levers that are to be equipped with nose irons shall have those portions of the lever ends receiving them machined for the full distance over which the nose irons are to move.

503. Leveling Lugs

In scales of the straight lever type, each lever shall be provided with leveling lugs for longitudinal alinement. In scales of the torsion lever type, leveling lugs shall be provided on the pipe or torsion member for transverse alinement, and on the extension arm for longitudinal alinement. Each pair of lugs shall be spaced 11 inches apart. The leveling surfaces of each pair of lugs shall be finished to a common plane, which shall be parallel to the plane through the knife-edges of the end pivots.

504. Marking of Levers

Figures denoting the ratio of each lever shall be cast or otherwise permanently marked on the lever.

505. Permanency of Adjustment

The design, workmanship and factory adjustment of each lever shall be such that the ratio of the lever arms established by the relative positions of the pivot knife-edges will be within 0.02 percent of the nominal ratio.

53—VI PIVOTS AND BEARINGS

601. Material

The material used for pivots and bearings shall be special alloy steel, S.A.E. 6,195 or S.A.E. 52,100, hardened to Rockwell C scale not less than 58.

602. Design and Manufacture

Pivots shall be so formed that the included angle of the sides forming the knife-edge will not exceed 90 degrees, and that the offset of the knife-edge from the center line of the pivot will not exceed 10 percent of the width of the pivot.

603. Mounting

(a) Fastening.—Pivots shall be firmly fastened in position without swaging or calking.

(b) Machined-in Pivots—When Required.—Pivots in main and extension levers shall be fitted into machined ways.

(c) Continuous Contact Required.—Pivots shall be so mounted that continuous contact of the knife-edges with their respective bearings for the full length of the parts designed to be in contact will be obtained. In loop bearings the knife-edges shall project slightly beyond the bearings in the loops.

604. Position

In any lever the pivots shall be so mounted that:

(a) Each knife-edge will be maintained in a horizontal plane under any load within the capacity of the scale.

(b) A plane bisecting the angle of a knife-edge will be perpendicular to the plane through the knife-edges of the end pivots.

(c) The actual distance between the end knife-edges of any lever will not differ from the nominal distance by more than 1/64 inch per foot.

(d) The knife-edges in any lever will be parallel.

605. Support for Projecting Pivots

The reinforcing on the levers to support projecting pivots shall be tapered off to prevent accumulation of dirt next to the pivots and to provide proper clearance.

606. Fulcrum Distance

The distance between knife-edges of fulcrum and load pivots of main levers shall be not less than 8 inches.

607. Location of Main Lever Load Knife-Edges

The load knife-edges of main levers shall be so located that the center line of the weigh rails can be placed in the plane established by vertical lines through the centers of the knife-edges.

608. Design of Bearings

Bearing steels and the parts supporting or containing them shall be so applied to the mechanism that permissible movement of the platform will not displace the line of contact between any bearing and the opposing pivot.

609. Interchangeability of Bearing Steels

All bearing steels of the same nominal dimensions or parts identification shall be interchangeable or mounted in interchangeable bearing blocks. The interchangeable part shall be securely mounted in the part containing it.

610. Finish of Bearing Steels

The bearing surfaces shall be brought to a smooth, true and accurate finish to provide continuity of contact with opposing pivots.

53—VII NOSE IRONS

701. Design

Nose irons shall be so constructed that:

(a) They will be positioned by means of adjusting screws of standard size and thread.

(b) They will be retained in position by means of screws or bolts of standard size and thread.

(c) The surfaces of nose irons intended to be in slidable contact with the levers will be machined true, so as to obtain an accurate fit in or on the levers.

(d) When adjustments are made, the knife-edge will be held parallel to its normal position.

702. Screws and Bolts

Adjusting and retaining screws and bolts shall be made of a corrosion-resistant material.

703. Retaining Device

A device for retaining each nose iron in position shall be provided, and shall be so designed and constructed that:

(a) It will be independent of the means provided for adjustment.

(b) It will not cause indentation in the lever.

(c) Loads applied to the scale will not cause tension in the retaining bolts.

(d) The nose iron will remain in position when the retaining device is released.

704. Marking of Position

The position of each nose iron as determined by the factory adjustment shall be accurately, clearly and permanently indicated by well defined marks on the lever and nose iron which meet on a common line.

53—VIII LEVER FULCRUM STANDS

801. Qualities of Castings

Castings for lever stands shall be smooth, clean, uniform, and free from blisters, blowholes, and shrinkage holes and cracks.

802. Proportions

Lever stands shall be so designed, constructed and installed that, under any practical condition of loading, the resultant force through the bearing will fall within the middle third of the length and width of the base.

803. Bases for Lever Stands

The base of any lever stand shall be smooth, or shall be finished in any suitable manner within a tolerance of 1/32 inch to a plane perpendicular to a vertical line through the center of the knife-edge bearing carried by the upright portion of the stand.

804. Finish of Tops of Stands

The top of any lever stand receiving a bearing steel, cap or block shall be finished smooth and shall be parallel to the base within 1/32 inch.

805. Anchor Bolt Holes

Four or more anchor bolt holes, not less than 2 inches in diameter, shall be provided in proper places in the base of every fulcrum stand, unless other equally effective means for anchorage are provided.

806. Tie Bars

When tie bars for lever stands are used, contacting surfaces shall be machined.

53—IX LOOPS AND CONNECTIONS

901. Material

The requirements for material and hardness of bearing surfaces in loop connections shall be the same as those prescribed herein for pivots and bearings.

902. Design

In loops which form bearings for projecting pivots, the radius of the portion of the bearing making immediate contact with the knife-edge and the radius of the eye of the loop shall not be less than the longest side of the cross-section of the square pivot to be used in the loop, and like clearance shall be provided if pivots of other than square cross-section be used.

903. Length

Loops in like connections, except when adjustable, shall be of the same length.

904. Steelyard Rod

The steelyard rod shall be equipped with a turnbuckle.

905. Locknuts

Bolts or turnbuckles used as parts of connections shall be provided with locknuts.

53—X CHECKS

1001. Number, Type and Kind

Weighbridge checks shall be provided equivalent in functioning to not less than two longitudinal checks on each end and two transverse checks on each side, of the rod type. Checks of the rod and bumper types shall be adjustable.

1002. Position

Checks shall be set in the same horizontal plane and as high as possible. Longitudinal and transverse checks designed to take tension shall be respectively parallel and perpendicular to a vertical plane through the center line of track.

1003. Strength

Checks of the rod type shall be designed to act only in tension. The checks at either end or side shall be designed to resist the forces prescribed in Table 1415. Other types designed to take tension shall be calculated for equivalent strength.

TABLE 1415

FORCES TO BE ASSUMED IN THE DESIGN OF CHECK RODS FOR TWO-SECTION, KNIFE-EDGE RAILWAY TRACK SCALES

Sectional Capacity (tons)	*Scale Length* (feet)*	*Each Lateral Check (pounds)*	*Combined Longitudinal Checks (pounds)*
150	50	27,500	64,000
150	60	29,000	73,000
200	60	29,000	85,000
200	75	31,000	101,000

* For scale lengths intermediate to those shown, the values of the forces may be interpolated.

53—XI WEIGHBEAMS AND ACCESSORIES

1101. Design

(a) Limits for Weighbeam Capacity.—See Article 104.

(b) Full-Capacity Weighbeam.—Except for special cases, a weighbeam of the full-capacity type shall be provided.

(c) Poise Stop.—On each bar of the weighbeam a poise stop shall be provided to prevent the poise from traveling and remaining back of the zero notch or graduation.

(d) Notches.—On main bars the notches shall be spaced not closer than 6 to the inch. Each notch shall be so made that when the pawl rests in it a line projected from the center of the side of the notch nearer the zero graduation to the axis about which the pawl rotates will be perpendicular to that side of the notch.

(e) Pawl or Latch.—The tip of the pawl or latch shall be of the same width as the notches of the weighbeam, and shall be rounded off so that a small amount of dust or dirt in the bottom of the notch will not prevent the poise from assuming the correct position.

(f) Projections and Recesses.—Poises shall be designed with the object of reducing to a minimum the number of projections that may become chipped or broken off, and recesses that may retain foreign material.

(g) Poise Bearings.—Each poise shall be constructed to move along its bar without side play. The main poise shall be equipped with ball bearings.

1102. Marking

(a) Intervals.—For scales with a main poise travel of not more than 400,000 pounds, the notches and graduations on the main bar shall be made at 1,000-pound intervals.

(b) Length of Graduation Marks.—For the main bar, the length of graduations other than those representing 0, 5, 10, 15, etc., thousand pounds shall preferably be 1.5 times the distance between their centers, but in no case greater than twice the distance between their centers. The length of graduations representing 5, 15, 25, etc., thousand pounds shall be not less than 1.5 times that of the intermediate graduations. The length of graduations representing 0, 10, 20, etc., thousand pounds shall be 0.75 inch.

(c) Size of Figures.—For the main bar, the zero graduation and every tenth graduation shall have its value in thousands of pounds (i.e., 0, 10, 20, etc.) marked by figures ⅜ inch in height, except the last graduation on the bar, which shall be marked in full (e.g., 300,000 pounds). The 5s, 15s, etc., may or may not have the value in thousands of pounds marked, or may have a star or other device placed opposite the graduation. All numbers shall be placed directly above or below their respective graduations, and shall be within 1/16 inch to ⅛ inch of the graduation.

1103. Registering Weighbeams

(a) Fractional Bar Stops.—On registering weighbeams, the fractional poise shall be equipped with means to insure a positive stop at any 20-pound interval, and a stop shall be provided to prevent the fractional poise from traveling and remaining beyond its proper limit in either direction.

(b) Operating Lever.—On registering weighbeams, a substantial type of hand grip shall be provided to facilitate the registration of the weight. The natural operation of the registering mechanism shall not cause lateral displacement of the weighbeam.

(c) Receptacle for Weight Ticket.—On registering weighbeams, means shall be provided to prevent the placing of the weight ticket in its receptacle in any position in which an incorrect weight can be registered.

(d) Type Figures.—On type-registering weighbeams, type figures shall be made of material sufficiently hard that under the designed conditions of use the figures will not become battered or defaced. The figures shall be plain and raised sufficiently to insure a clear impression upon the weight ticket. They shall be so attached that they cannot become loosened or detached without a positive indication that the weighbeam is out of order.

1104. Fractional Bars

For registering weighbeams, the graduations for the fractional bar shall be placed at 20-pound intervals up to and including 980 pounds, or, if the fractional bar corresponds to a full 1,000 pounds, the last figure shall be marked to read 999 pounds. Non-registering weighbeams, except for special cases, shall be graduated in 50-pound intervals.

1105. Balance Ball

The position of the balance ball shall be vertically adjustable. Unless otherwise required by law or regulation, longitudinal movement shall be controlled by means of a self-contained, hand-operated screw or other device which will not require the ball to be rotated.

1106. Counterbalance Weights

If counterbalance weights are to be used, the lower end of the counterbalance hanger shall be threaded, a cup for the loose balancing material shall be screwed to the lower end of the stem, and each additional weight shall be provided with an elongated hole in the center through which the hanger stem may pass. When no counterbalance weights are necessary on top of the counterbalance cup, the cavity shall be closed by a cover, secured in a positive manner. No counterbalance weights shall be used in any place in the scale except at the weighbeam. No slotted counterbalance weights shall be used.

1107. Ratio

A pivot with a loop shall be provided at the weighbeam tip. The ratio to this pivot shall be 7,000 or 10,000, or a multiple thereof. The ratio shall be plainly and permanently stamped on the weighbeam.

1108. Identification of Parts

Each weighbeam shall be given a serial number which shall be stamped on the weighbeam. The pivots, poises and fractional bar shall have stamped upon them identification marks to show to which weighbeam each belongs, and the pivots shall be so marked as to indicate their proper positions in the weighbeam.

1109. Factory Adjustment of Notches

Each weighbeam notch shall be adjusted to within 0.002 inch of the nominal distance from the zero notch.

1110. Beam Fulcrum Stand

(a) Type.—The weighbeam shall be supported on a stand fitted with compensating bearings. Beam fulcrum stands shall be so designed, constructed and installed that the resultant line of forces applied through the bearing carried by the stand will fall within the middle third of the length and width of the base.

(b) Finish.—The base of the stand shall be finished to a plane perpendicular to the axis of the upright portion of the stand, and the knife-edge line of the bearing shall be parallel to the base.

1111. Trig Loop

(a) Weighbeam Travel.—The play of the weighbeam in the trig loop shall be not more than 2 percent of the distance from the trip to the fulcrum pivot nor less than 0.9 inch.

(b) Pointer.—The weighbeam shall be fitted with an indicator to be used in conjunction with a graduated target or other device on the trig loop to indicate a central position in the trig loop when the weighbeam is horizontal.

(c) Material.—The contact parts of the trig loop shall be made of a non-magnetic material.

1112. Weighbeam Support

The weighbeam fulcrum stand and trig loop stand shall be supported on a metal shelf mounted on metal pillars, or equivalent in strength and durability. The shelf must be sufficiently rigid that, within the capacity of the scale, deflections cannot occur to such an extent as will affect the weighing performance.

53—XII ANTI-FRICTION POINTS AND PLATES

1201. Material and Design

Hardened steel anti-friction contacts shall be used to limit longitudinal displacement between knife-edges and bearings. They shall be smooth and so designed and applied as to provide contact at points on the knife-edge line.

1202. Clearances

The total clearance between anti-friction plates and points shall not exceed 1/16 inch on the weighbeam, ⅛ inch on the shelf lever, and ¼ inch on all other levers. The minimal clearance shall be not less than one-half these respective amounts.

53—XIII CLEARANCES

1301. General Requirement

The clearance around and between the fixed and live parts of the lever system shall be at least ¾ inch except at points where other clearances are specified.

53—XIV INTERCHANGEABILITY

1401. Identification Required

Units or parts of units intended to be interchangeable with like units or parts in scales of the same design and manufacture, shall be identified on the scale drawings or in

the subject-matter of the proposal in such a manner as will clearly indicate the interchangeable parts, the manner of replacement, and the adjustments required, if any, after replacement.

53—XV WEIGHBRIDGES

1501. Type of Girders

Girders shall be of the fish-belly type.

1502. Steel Specifications

Material and workmanship shall conform to the Specifications for Steel Railway Bridges—1938, published by the American Railway Engineering Association, punched and reamed work.

1503. Main Girders—Loading Assumptions and Required Section Modulus

For the sectional capacities and scale lengths listed, the section moduli of single weighbridge girders shall be not less than those shown in Table 1416. For scale lengths intermediate to those shown, the values of the section moduli may be interpolated.

TABLE 1416

REQUIRED NET SECTION MODULUS, ONE WEIGHBRIDGE GIRDER

Sectional Capacity (tons)	*Length of Scale (feet)*	*Length of Span (feet)*	*Assumed Dead Load per Girder (pounds)*	*Approximate Live Load—Cooper's Locomotive Loading*	*Required Section Modulus One Girder*
150	50	44	27,500	E–60	1,750
150	60	54	33,000	E–55	2,000
200	60	54	45,000	E–70	2,700
200	75	69	56,250	E–60	3,200

1504. Bracing

Each weighbridge shall be designed to resist a force of 300 pounds per foot of scale, uniformly applied laterally in either direction along the track, and a concentrated force of 20,000 pounds applied laterally in either direction at any point on the track.

(a) Diagonal Bracing.—Single diagonal bracing shall consist of not less than 3½-inch by 3½-inch by ⅜-inch angles.

(b) Transverse Bracing.—The ends of the weighbridge shall be provided with transverse bracing, of which the section modulus shall be not less than that determined by the formula

$$S = \frac{d\,(20{,}000 + 150\,L)}{18{,}000}$$

where S = the section modulus
L = the length of scale in feet
d = the distance in inches from the main lever load knife-edge to the top of the weigh rail

Intermediate transverse bracing, with section modulus not less than that determined by the above formula, shall be provided, spaced not farther apart than the distance between alternate stiffeners.

(c) Lateral Bracing.—Lateral bracing shall be provided between compression flanges, spaced not farther apart than the distance between intermediate transverse bracing, designed to resist compression shear equal to 5 percent of the axial stress in the compression flange of one girder.

(d) Stiffeners.—Not less than two pairs of stiffener angles shall be provided over each bearing of the girders and, in addition, suitable angle stiffeners shall be spaced not farther apart than the unsupported depth of the web plates. The ends of these stiffeners shall be milled to fit the girder flanges where bearing stress is transmitted from the stiffener to the flange.

NOTE: Attention is called to the reported economy and efficiency of welded stiffeners. When properly applied, welded stiffeners should be considered as meeting the requirements of this specification.

1505. Rivet Arrangement

Weighbridge girder flanges shall be connected to the web with enough rivets to transmit to the flange section the horizontal shear at any point, together with any load that is applied directly on the flange. Wheel loads shall be assumed to be distributed over 3 feet of flange. Rivets in end stiffeners shall be sufficient to develop the full computed stress in the stiffeners.

(a) Pitch.—The pitch in the direction of stress shall not exceed 7 times the diameter of the rivets (or not over 3½ inches in the connection between the web and flange section), and the distance between centers of rivets shall be not less than 3 times the diameter of the rivets.

(b) Edge Distance.—The distance from the center of a rivet to a sheared edge shall be not less than 1¾ times the diameter. The distance from the center of a rivet to a rolled or planed edge shall be not less than 1½ times the diameter, except that this distance may be not less than 1¼ times the diameter in the flange of a beam or channel. The distance from the center of a rivet to the edge of a plate shall not exceed 8 times the thickness of the plate.

1506. Fabrication and Assembly

Weighbridges shall be assembled and riveted up complete with all bracing, except lower flange transverse and diagonal bracing, in the shop under proper inspection.

1507. Weigh Rail Pedestals

The weigh rails shall be carried on metal pedestals, spaced not over 30 inches center to center, which shall be mounted on metal ties or directly on the weighbridge. The tops of pedestals shall be machined. The bottoms of pedestals shall be machined unless type metal or equivalent is to be poured between the bottoms and the surfaces supporting them.

1508. Weigh Rails

The weight of the weigh rails shall be not less than 100 pounds per yard. New rails shall be used. If splices are necessary, they shall be accurately applied.

1509. Clearance Along Weigh Rails

The clearance between weigh rails, or their pedestals, and the rigid deck shall be not less than 1.5 inches. The openings shall be protected from weather and dirt.

53—XVI—TRANSVERSE BEAMS SUPPORTING APPROACH RAILS

1601. Section Modulus

The transverse beams at each end of the scale shall each have a section modulus of not less than 250 for 200-ton per section scales, or 197 for 150-ton per section scales.

1602. Fastening

The transverse beams shall be held at the ends by metal supports designed for line contact transversely with the beams. The supports shall be securely fastened to the foundation.

53—XVII PROTECTION FROM CORROSION

1701. Surface Finish and Treatment

The finish and treatment of all surfaces shall be such as to insure good appearance and satisfactory resistance to corrosion. The surface treatment shall be durable and appropriate to the intended uses.

53—XVIII APPROACH RAILS

1801. Anti-Creep Provisions

Positive means shall be provided to prevent creeping of approach rails, and to maintain a clearance, which shall be not less than ¼ inch nor more than ¾ inch, between the approach rails and the weigh rails unless some special means is used to reduce impact when wheel loads pass from approach rails to weigh rails or vice versa.

1802. Easer Rails

Easer rails, or load transfer devices, if used, shall be so constructed as to leave no lateral or vertical restraint upon the weigh rails when the device is unloaded.

53—XIX DECK

1901. Type

Unless a scale is used to weigh other loads than freight cars of standard gage, the deck shall be of the fixed type.

1902. Construction

The deck shall be surfaced to conform to safety requirements, shall be sufficiently strong to support the incidental traffic, and shall be waterproof.

1903. Clearance

The clearance between the bottom of the fixed deck beams, or deck supports, and the weighbridge girders shall be not less than 2 inches.

53—XX EXCLUSION OF DIRT AND PRECIPITATION

2001. General Requirement

Means shall be provided to prevent accumulation of dirt or other foreign material in or about the pivots, bearings, or other parts, whereby interference with the action of the scale or undue deterioration of any part of the scale might result.

53—XXI—LIGHTING

2101. Weighbeam, Scale House and Deck

Lighting for the weighbeam, scale house and deck shall be provided, adequate for the needs of safe operation and to enable the weigher to read the weighbeam and observe car numbers and light weights and the position of car wheels with certainty.

2102. Pit

The pit shall be provided with sufficient illumination to permit the ready and complete inspection of the scale parts.

53—XXII LOCATION AND ELEVATION

2201. Foundation

Scales shall be so located that an adequate foundation and at least 50 feet of tangent track at each approach to the weigh rails can be provided.

2202. Elevation

The scale shall be raised with respect to the yard to such an elevation that surface water will drain away from it. Means shall be provided to prevent surface water between the rails of the scale track from running into the pit.

2203. Right-Handed Weighbeam

Scales shall be so located that levers other than the shelf lever between the transverse extension lever and the weighbeam are not necessary. Right-handed weighbeams are always to be preferred.

53—XXIII FOUNDATION AND PIT

NOTE: This section presumes that a scale pit fully enclosing the scale mechanism is necessary. When conditions permit, however, consideration should be given to the possibility of installing scales on foundations without side walls, since this conduces to better maintenance, especially in the lower latitudes.

2301. Material

All scale foundations shall be constructed of concrete. The quality of materials and methods of mixing and placing the concrete shall conform to the specifications of the American Railway Engineering Association for Class A concrete.

2302. Dimensions of Pit

The depth of the scale pit shall be not less than 7 feet from the base of the weigh rails to the finished floor. The width between faces of side walls shall be not less than 10 feet, provided there shall be a horizontal clearance of not less than 16 inches between the faces of the side walls and the scale parts below the weighbridge and above the bases of the stands. The length inside the end walls shall be not less than 2 feet greater than the length of the scale assembly.

2303. Walls of Pit

The side and end walls shall be not less than 15 inches (preferably 18 inches) thick at the top. The foundation walls of the scale house shall be not less than 12 inches thick at the top and shall be solidly formed to the side walls of the scale pit.

2304. Waterproofing

Where necessary to prevent seepage of water through foundations, scale pits shall be membrane-waterproofed, or waterproofed by methods equally effective.

2305. Drainage

The pit floor shall be pitched to a common point for drainage and shall be smooth and free from pockets in which water may stand. If the pit floor is below subsurface

water level, the pit shall be drained from its lowest point into a sump adequately equipped with automatic means for removal of water as it collects.

2306. Approach Walls

Approach walls or piers of concrete shall be built to extend 15 feet (preferably 25 feet) from the pit face of the end walls and back under the track to preserve line and surface of tracks. They may be built of a solid mass of concrete or may consist of parallel walls or piers; however, the latter construction shall have a single footing supporting both walls. Where necessary to obtain safe bearing capacity the approach walls shall extend to the same depth as the pit walls.

2307. Wall Batter

Wall surfaces next to earth subject to freezing shall be constructed with a batter of not less than 1 to 12. For extreme low temperatures, the batter should be not less than 1 to 6, and should extend not less than 3 feet below the ground surface.

2308. Footings or Piers for Lever Stands

Concrete footings or piers supporting the lever stands shall be not less than 30 inches thick. Their tops shall be above the floor a sufficient distance to prevent the accumulation of water under the bases of stands, and shall be finished to exact level and elevation to receive the lever stands directly without the use of shims or grouting. If the scale is of a type having main levers or parts of the bearing assemblies that hang below the bases of the main lever stands, the piers shall be provided with recesses of a size to give clearance of not less than 1.5 inches, and so formed as to prevent accumulation of dirt. (See also Article 307.)

2309. Pit Floor

The floor of the pit may be a mat of concrete approximately as thick as that required to support the main lever fulcrum stands, or, if local conditions permit, the thickness may be reduced to not less than 6 inches. (See Article 2305 for rainage requirements.)

2310. Anchor Bolts

Anchor bolts embedded in concrete a minimum of 15 inches shall be provided in foundations for lever stands to match the bolt holes provided for securing the stands.

2311. Up-Pull Levers

Up-pull levers (floating levers) shall be anchored to resist not less than twice the up-pull produced by the capacity live load.

2312. Weighbeam Foundations

The pillars supporting the weighbeam shelf shall rest upon a reinforced concrete floor, or steel beams, or reinforced concrete beams, but the pillars and supporting beams, if used, shall be independent of the scale house floor if it is of timber. When necessary to install the weighbeam in a building other than a regular scale house, the pillar support shall rest on foundations independent of the building.

2313. Ventilation

Scale pits shall be ventilated to meet the needs of each particular case, the object being to prevent condensation on the metal parts.

2314. Entrance to Scale Pit

Entrance to the scale pit shall be either through the floor of the weighbeam house or the foundation wall, preferably the latter. The opening shall be closed by a door suitably fastened to prevent unauthorized entry.

2315. Safety Piers

Suitable piers, columns, or other supports should be provided to prevent excessive drop of the girders should failure of the scale parts occur.

53—XXIV SETTING OF THE SCALE

2401. Fastening of Stands

After alining the lever stands, the anchor bolt holes in the castings shall be filled with cement or other suitable material, washers applied to the anchor bolts, and the nuts run solidly home.

2402. Alinement

All levers shall be level and connections plumb.

53—XXV WEIGHBEAM HOUSE

2501. Design

Except where the weighbeam is mounted in an adjacent building, a suitable and substantial house shall be provided for the weighbeam and weighing office. The minimal inside width of the house shall be 4 feet, and the minimal length shall be sufficient to allow the installation of a shelf and weighbeam of proper capacity, together with accessories. It shall be provided with a bay window, or front and end windows, located with the sill about on a level with the top of the beam shelf, and of sufficient size to give the weigher a clear and unobstructed view of the scale deck and approaching cars. The windows shall be glazed with clear glass, or clear wire glass, free from imperfections.

2502. Clearances

(a) Beam Shelf.—A clearance of not less than 1 inch shall be provided between the inside of the scale house and the weighbeam supports and shelf.

(b) Track.—The lateral clearance between the scale house and the center of any track shall be not less than 7 feet 6 inches, if not otherwise required by law or by the purchaser.

2503. Ventilation

A suitable roof ventilator shall be provided for the scale house.

53—XXVI SENSIBILITY RECIPROCAL

2601. Definition

The sensibility reciprocal is the change in load required to turn the weighbeam from a position of equilibrium in the center of the trig loop to a position of equilibrium at either limit of its travel.

2602. Limit

The sensibility reciprocal shall not exceed 50 pounds.

53—XXVII TOLERANCE

2701. Acceptance Tolerance

The tolerance in excess or deficiency on the first field test, after installation corrections, is 0.05 percent of the applied load, or 50 pounds per 100,000 pounds of applied load, for any position of the test weight car on the weigh rails. The procedure outlined in the "Definition of a Standard Test of a Railway Track Scale" shall be followed.

PROPOSED REVISION OF CERTAIN ITEMS OF SECTION 54—SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF MOTOR TRUCK, BUILT-IN, SELF-CONTAINED AND PORTABLE SCALES FOR RAILWAY SERVICE

1936

Page 14–90, Manual—

Section 510 sets forth formulas for use in computing bending moments in concrete slabs due to wheel loads. One of the symbols used is

W = the width of tire in feet

It is proposed to add to this definition the words "(or the permissible wheel load in pounds, divided by 12,000)", making the entire line read

W is the width of tire in feet (or the permissible wheel load in pounds, divided by 12,000)

Page 14–92, Manual—

Section 603–a specifies the live load assumptions for use in the design of a motor truck scale, and reads

(a) Motor Truck Scales: For the design of motor truck scales, the live load shall be assumed to be a five-axled vehicle whose wheel gage, axle spacing and axle loadings are as shown in Table 1408.

It is proposed to add to this paragraph the following—

For the general purposes of design, the vehicle shall be assumed to be positioned with its longitudinal axis between the weighbridge girders and parallel to the longitudinal center line of the scale, with one series of wheels in the vertical plane through the web of one weighbridge girder. For the end and corner reactions, one rear wheel shall be assumed over the center of a main load bearing. No lateral or longitudinal distribution of the wheel loads shall be assumed.

Page 14–101, Manual—

Section 2101 now reads

Scale foundations resting upon or extending into the ground shall be constructed of concrete. (See Paragraph 515.)

It is proposed to add to this paragraph the following—

The quality of materials and methods of mixing and placing the concrete shall conform to the specifications of the American Railway Engineering Association for Class A concrete.

Appendix C

(5) BIBLIOGRAPHY ON SUBJECTS PERTAINING TO YARDS AND TERMINALS

E. E. R. Tratman, Chairman, Subcommittee

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Appendix D

(6) SUBSTITUTION OF OUTLYING YARDS AND FACILITIES FOR YARDS AND OTHER LARGE FACILITIES IN CITIES WHERE LAND VALUES ARE HIGH

W. H. Giles, Chairman, Subcommittee; J. R. W. Ambrose, C. E. Armstrong, C. J. Astrue, W. O. Boessneck, F. T. Darrow, C. U. Smith.

After the business slump of 1921, car loadings began to increase and reached a new peak in 1926. The continued increase in traffic soon overtaxed many of the freight yards, engine terminals, freight and passenger handling facilities, and other operating facilities of the railways. In order to handle the business expeditiously and economically some expansion or revamping of the plant was necessary. In some cases a revamping of the old facility to increase efficiency could be done but in many cases a survey would show that the desired results could not be obtained by revamping or expansion in the existing location, particularly in view of an anticipated continued increase of traffic in the future. The most perplexing problems were to be found in the congested areas of large cities where one or more relatively small train yards, engine terminals, repair plants, freight houses and other facilities had been taking care of the normal traffic until the car loading curve began to turn upward.

The problems in the large cities involved consideration of many factors other than providing a plant of satisfactory design. During the previous years the city had grown up around the railway until the space available for expansion was limited; the cost to secure additional property was excessive; streets crossing the projected area would have to be closed or the crossings separated; the city required the extension of other streets formerly closed by the original facility; governmental restrictions limited the hours of switching in the yards because of the noises or for other reasons; and the demand for smoke abatement was threatening to force a replacement of the steam locomotive with gas or electric.

These conditions prompted the consideration of outlying yards and other large facilities.

Your committee has undertaken the study of this subject by submitting a questionnaire to 69 of the principal railways serving the large cities of the United States and Canada, requesting a report where outlying facilities, such as train and classification yards, engine terminals, freight handling facilities, etc., had been constructed to replace or supplement, as to function, certain inlying facilities of a similar type in congested areas. These railways reported 19 projects, 17 of which had been completed during the period from 1923 to 1930, and 2 during 1918.

In 18 cases, inadequacy of the existing facility was given as one of the contributing reasons for making the change. Due largely to a decrease in traffic, the use of five of these outlying facilities has been permanently or temporarily discontinued since 1930 and operations resumed in the old inlying facility. One has been partly discontinued. In one of these cases, the proposed facility was abandoned before it was completed.

Of course, it must be assumed that inadequacy was not the only reason in every case for providing the outlying facility because expansion or revamping of the existing facility could have been accomplished, if space were available and could have been secured and utilized at a reasonable cost. In the 18 cases of reported inadequacy, expansion of the inlying facility was considered uneconomical for various reasons; including high land values, excessive cost of securing additional land, topography, grade separations involved and objections of the city government.

In each case where the outlying facility has been continued in use, the space formerly occupied by the inlying facility, if owned by the railway, has been utilized for other purposes; including industrial sites, team tracks, interchange yard, repair facilities, or as a zone yard for handling local traffic. However, none of the changes was made because the space occupied by the inlying facility was needed for other purposes.

Where the new outlying facility is being operated, it is reported that the service to local shippers has been improved and traffic through the terminal has been expedited. In general, these facilities are considered economical by the owners, although the anticipated reduction in unit costs has not been realized in every case.

Other railways have considered replacing inlying with outlying facilities in the past, but for various reasons, the change was not made. In some of these cases the outlying property has been purchased for development in the future.

With a material increase in traffic or change in business requirements in a specific locality, and in existing cases where governmental restrictions are burdensome, it will be necessary to make extensive studies to develop the most economical and efficient plans for the future.

The study of each terminal should develop the facts regarding the existing facilities, method of operation and traffic handled. Some of the reasons for making a change in the facilities include:

1. Obsolescence or inadequacy.
2. Consolidation of separate facilities. (Such as engine terminal and train yard).
3. Consolidation of the operations of several small yards in a new facility and confining the small yards to zone switching operations.
4. Co-ordination with other railways.
5. Delays to road trains.
6. Delays to switching movements.
7. Delay in interchange.
8. Change in method of operation.
9. Public body regulations:
    (a) Switching restricted to certain periods during day.
    (b) Street crossings.
    (c) Grade separations.
    (d) Smoke abatement.

Some things to be considered when developing plans for a new facility include:

1. Service to shipper and consignee.
2. Ratio of fast trains to slow trains handled.
3. Possible delays at outlying facility and extra handling of cars.
4. Increased switching at outlying facility:
    (a) for local business,
    (b) to reduce switching at on-line terminals or division points.
5. Possible readjustment of road train schedules.
6. Careful and complete determination of operating procedure for new outlying facility is essential to complete analysis.
7. Limiting traffic in inlying facility to that requiring preferred handling and run fast trains direct.
8. Limiting facility to normal requirements (not peak load) with provision for nominal future expansion. (This will result in increased operating cost during peak load).
9. Complete diagnosis to determine whether some exterior condition is responsible for or contributes to the inadequacy of inlying facility; such as inefficiency and unreliability of road power and switch power, quality and quantity of water and fuel supplies, capacity of main lines and arrangement of facilities.

Some possible advantages of new outlying facilities are:

1. Consolidation of forces.
2. Improved interchange.
3. Reduction in road train time.
4. Better classification of outbound road trains, thereby reducing amount of switching at intermediate terminals and division points.
5. New facilities are modern and result in economies through efficiency.
6. Potential value of space occupied by inlying facility for industrial sites and other purposes.

Some possible disadvantages of new outlying facilities are:

1. Cost of the facility.
2. Increase in delivery time.
3. Increased local switching and transfer movements.
4. Necessity for increased classification at intermediate terminals and division points; to block inbound trains for faster terminal distribution.
5. Traffic loss on account delay of small amount of traffic affecting a particular industry's business and penalizing by that industry at other points.

Progress report, offered as information.

Appendix E

(7) CLASSIFICATION YARDS

Collaborating With Committee 16—Economics of Railway Location and Operation

G. F. Hand, Chairman, Subcommittee; C. E. Armstrong, C. J. Astrue, Hadley Baldwin, W. O. Boessneck, N. C. L. Brown, H. F. Burch, W. F. Cummings, F. T. Darrow, R. B. Elsworth, W. H. Giles, J. L. Gressit, R. J. Hammond, M. J. J. Harrison, E. M. Hastings, W. H. Hobbs, Noah Johnson, E. T. Johnston, P. L. Koehler, E. K. Lawrence, L. L. Lyford, C. H. Mottier, T. R. Ratcliff, W. B. Rudd, W. C. Sadler, C. U. Smith.

This year the subcommittee has selected the special subject of "Study of the Hump End of the Receiving Yard" with the purpose of discussing and setting down certain principles of design, in respect to the track arrangement and grades in this portion of hump classification yards, that should receive careful consideration, so as to permit prompt and economical handling of cars.

When a freight train comes to a stop in the receiving yard the road engine must be released, and the track arrangement should be such as to permit this to be done quickly and with a minimum interference with humping operations. This necessitates a connection from all receiving tracks to an engine track or other open track for the movement of engines without passing over the hump. The preferable method is to connect this engine track to the hump lead between the throat of the receiving yard and the hump crest, usually close to the throat of the yard; this connection often can be used also for a hump runaround track. It is obvious that road engines cannot be released in this manner while a train is being humped, but it provides the quickest way of releasing engines from *all* receiving tracks and the *least* interference with humping operations. A track connecting to some of the receiving tracks may be provided but this does not provide quick exit from all of the tracks and should be considered only as a facility additional to that described above.

To expedite freight movements, there has been a recent trend toward making up trains that can be run to destination through or past intervening yards without classification, so far as this is possible. Where this method is not practicable for the whole train, part of the train may be handled through the yard without classification over the

hump and the remainder classified for various destinations. This makes a "hump runaround track" a very desirable adjunct, to permit prompt handling of cars not requiring classification. In modern hump yards designed for continuous movement of cars in one direction from the receiving yard to the classification yard, such handling requires that the runaround track be connected so as to serve all receiving tracks at the hump end, unless trains containing cars not requiring classification over the hump can be assigned to certain tracks in the receiving yard and the runaround track connected only to these receiving tracks. The engine release track and the runaround track often can be consolidated.

The gradient through the receiving yard and up to the hump usually will be governed by the topography of the ground on which the yard is located. Ordinarily the grade through the receiving yard rises toward the hump, with a sharper rise from the throat of the yard up to the hump in order to meet the desired elevation at the summit. An adverse grade approaching the summit of the hump is necessary in order to bunch the cars and permit them to be uncoupled readily. However, care should be taken that the total adverse gradient is not a limiting factor in respect to the power required for the humping operation.

The various operations and track connections between the throat of the receiving yard and the hump summit will govern the distance between these two points. If an underground inspection pit in the hump lead is desired, this distance must be lengthened. However, all required facilities should be designed to occupy a minimum of distance, with the throat of the yard as close as possible to the hump summit. The use of lap switches will often aid in reducing this distance to a minimum.

When cars come together on the classification tracks the couplers should be lined up so they will couple. It is therefore desirable that the cars be on tangent track when the cut is made. This tangent is essential in a hump yard equipped with car retarders or with a scale on the hump. The general arrangement of the yard and of the portion under discussion should be such as permit the man making the cuts to stand on the right hand side of the hump lead (when looking toward the classification yard) so that the forward coupler of each cut is opened.

To summarize the above, the following principles should be observed in designing this part of a hump classification yard:

1. Provision for the quick release of road engines with minimum interference to humping operations.

2. Provision for hump runaround track for handling cars that do not require classification over the hump.

3. The gradient approaching the summit of the hump should be adverse and sufficient to permit the cars to be uncoupled readily.

4. The throat of the receiving yard should be located as close as possible to the hump summit. Provision for an underground inspection pit in a hump lead will affect this distance.

5. It is advisable to have at least two car lengths of tangent track ahead of the hump. If the classification yard is equipped with car retarders or with scales on the hump, this tangent track is essential.

Progress report, offered as information.

REPORT OF COMMITTEE 25—WATERWAYS AND HARBORS

G. P. Palmer, *Chairman;*
H. T. Bradley,
D. J. Brumley,
E. G. Day,
Benjamin Elkind,
W. D. Faucette,
R. P. Forsberg,
I. W. Geer,
G. F. Hand,
N. D. Hyde,
G. A. Knapp,
H. S. Loeffler,
R. J. Middleton,
F. E. Morrow,
W. G. Nusz,
V. B. W. Poulsen,
A. N. Reece,
P. T. Simons,
*L. W. Skov,
E. H. Roth, *Vice-Chairman;*
G. R. Smiley,
Chester K. Smith,
C. U. Smith,
J. L. Starkie,
A. B. Stone,
W. R. Swatosh,
E. F. Wendt,
S. L. Wonson,
Committee.

* Died, November 16, 1938.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Breakwaters, bulkheads and jetties. Progress in study—no report.

3. Warehouse piers, coal piers, car float piers and others on the Great Lakes and seacoast, collaborating with Committee 6—Buildings and 14—Yards and Terminals. Final report on Coal Piers (Appendix B) presented as information.

4. Economic principles involved in clearances over navigable waterways. Progress in study—no report.

5. Seawalls and ocean shore protection, including effect of wave action and ice. Subcommittee reports progress in study on seawalls—no report.

6. Reasonable life of steel casings immersed in sea water. Subcommittee reports collaboration with U. S. War Department in tests. Progress in study—no report.

7. Selection of type of construction of piers in various kinds of water, including materials used therein. Progress in study—no report.

8. Lands subject to servitude of navigation as affecting protection of roadbeds built or to be built on proposed dam pool areas. Progress in study—no report.

The Committee on Waterways and Harbors,
G. P. Palmer, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

E. H. Roth, Chairman, Subcommittee; G. P. Palmer, D. J. Brumley, W. D. Faucette, Geo. F. Hand, H. S. Loeffler, R. J. Middleton, C. U. Smith, W. R. Swatosh.

The committee recommends minor revisions of the Principles appearing in the Manual on page 25–13, these revisions, as indicated below, being confined to the addition of the words underlined and the deletion of "bridging" in the first line of Paragraph 1, under Allocation of Expense for the Construction, Maintenance and Operation of Bridges over Navigable Waterways.

CLEARANCES FOR STRUCTURES OVER NAVIGABLE WATERS

Proper clearances for structures over navigable waters are those that will not interfere unduly with the operation of either land or water transportation, cause unwise

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expenditures to be made for physical readjustments, or place burdensome restrictions on their future expansion. There must be an economic balance in the interest of both forms of transportation.

ALLOCATION OF EXPENSE FOR THE CONSTRUCTION, MAINTENANCE AND OPERATION OF BRIDGES OVER NAVIGABLE WATERWAYS

1. Any agency providing facilities for land transportation when [bridging] constructing a new crossing of a navigable waterway in its natural state, an improved waterway, or an artificial waterway, should assume the expense (but not more than) of constructing, maintaining and operating the bridge and other collateral facilities reasonably necessary to permit the use of such waterway in its condition at the time the crossing is made.

2. Where a navigable artificial waterway is constructed across existing land transportation routes, the governmental authority in charge of and providing the funds for the waterway project should bear the entire expense of constructing, maintaining and operating bridges and other collateral facilities required on account of such crossing, not only as originally made, but all changes or alterations made thereafter on account of changes in the waterway or the character of traffic on such waterway.

3. When a navigable waterway is improved by widening, straightening, deepening or otherwise, or the character of traffic on the waterway is changed by improvements elsewhere, or by changes in the design of vessels using the waterway, or by changes in methods of waterway transportation, which require changes in the bridges or other collateral facilities carrying land transportation agencies over such waterway, the governmental authority in charge of and providing the funds for the waterway should bear the expense of making such changes in the bridges or other collateral facilities, and the additional expense of maintaining and operating such altered bridges or facilities over and above the expense of the maintenance and operation of the bridges and facilities as they existed before such changes were made.

4. Any agency providing facilities for land transportation, crossing a navigable waterway, requiring, for its own purposes, changes in the bridges carrying it over the waterway, its collateral facilities, or in the waterway itself, should bear the expense of making such changes and the additional expense of maintaining and operating such altered bridges or facilities over and above the expense of the maintenance and operation of the bridges and facilities as they existed before such changes were made.

Appendix B

(3) WAREHOUSE PIERS, COAL PIERS, CAR FLOAT PIERS AND OTHERS ON THE GREAT LAKES AND SEACOASTS

W. R. Swatosh, Chairman, Subcommittee; E. G. Day, Benjamin Elkind, George F. Hand, W. G. Nusz, V. B. W. Poulsen, C. U. Smith, J. L. Starkie, S. L. Wonson.

Coal Piers at Inland and Coastal Ports

This report is intended to cover only the general features encountered in the design and construction of coal piers. The mechanical features for handling coal, the track layout, etc., are covered in some detail in a report prepared by the Yards & Terminals Committee, appearing on pages 335 to 343 of the 1936 Proceedings.

A study of reports on piers prepared by the United States Army Engineers discloses that coal pier structures in the various inland, coastal and river ports are designed principally for the transfer of coal from rail to vessels or barges. In some of the river, Great Lakes and New England ports they are designed for the transfer of coal from vessels to storage and rail. The report will be so subdivided.

Ports in New England

Piers handling coal in the New England tidewater area are both of the quay and pier types and to avoid confusion they will be hereinafter referred to as coal piers. Coal pier structures are of the following types: (a) Solid fill retained by seawalls or other types of bulkhead, (b) solid fill retained by some type of bulkhead with open pile and timber apron, (c) open pile and timber construction with bulkhead at the shore end. The bulkhead or seawall at the shore end is generally of stone or concrete, backed with solid fill, but steel and timber sheet piling are also used. The quay type of pier generally extends out in front of the bulkhead wall from 30 to 40 ft.

The coal piers are constructed without a superstructure except for towers, trestles, columns and mechanical conveying systems. The lengths vary from 325 ft. to 900 ft., while the widths range from 19 ft. to 100 ft. Where bulkhead construction is used, the bulkheads vary from 160 ft. to 2,250 ft. in length. Dock floors range from 11 to 16 ft. above M.L.W. The elevation of the floor is in no way dependent upon the level of the vessels' deck, as coal is lifted vertically.

A coal pier in Salem, Mass., is constructed with its floor 30 ft. above M.L.W. In New England berthing depths range from 14 to 35 ft. below M.L.W. The allowable floor loads of the pile and timber structures are not less than 1,000 lb. per sq. ft.

The foundations for coal discharging towers, trestles or columns on which are mounted traveling cranes or conveying equipment, coal pockets, or coal storage bridges are either incorporated in the pile and timber structure or constructed separately if on solid fill. In some cases the traveling or stationary coal discharging towers or cranes are placed above coal pockets, and the pocket columns are supported by pile clusters to insure safe bearing.

Coal storage areas are located on solid fill, either adjacent to coal discharging towers or cranes or may be somewhat removed therefrom, and the coal is distributed to them from the discharging equipment by belt conveyor, cable railroad, scraper conveyor, storage and reclaiming bridges, trestles with dump cars, or combinations of these.

In Portland, Me., there is a pier 965 ft. long by 125 ft. wide with four surface tracks extending on it a distance of approximately 400 ft. from the shore end. A high trestle is located along one side of the pier on which three traveling jib-cranes are mounted having reaches of 60 ft. Coal is distributed by cableroad to a 5,000-ton railroad loading pocket located over the tracks and also to the storage area in the rear of the structure.

Ports on the Eastern and Western Seaboards, Gulf and Rivers, Exclusive of New England Ports

Coal piers located at ports on seaboards are used for the transfer of coal from rail to vessels and barges and in some instances from vessels and barges to rail, for coaling tugs, bunkering, mercantile use and export. At many points coal is unloaded by gravity from a trestle constructed on the pier.

The prevailing types of coal piers are open pile and timber constructions. Generally, the piles are cut off at low water and capped. The bulkheads or seawalls are similar in construction to those described in New England ports. In recent construction work, there have been erected piers of steel supported on concrete filled steel cylinders and also steel

supported on concrete and steel piling. In Charleston, S. C., there is one case where the timber deck is supported on creosoted piles encased in concrete. In coastal water infested with marine borers, the piers are generally constructed of creosoted timbers and piles. In some instances on the west coast, piles have been sheathed in copper or encased in concrete. This type of pile protection has not proved to be very satisfactory because of liability to injury in handling and from contact with boats, flotsam or drift.

A modern coal pier was constructed by the Norfolk & Western Railway in 1936. Its substructure construction is hereinafter described in this report and illustrated in Fig. 1.

Coal piers range from 20 ft. to 168 ft. in width and from 105 ft. to 3,500 ft. in length. In New York harbor, a pier 259 ft. in width was constructed to provide for two car dumpers. Pier-floor elevations above M.L.W. vary from 5 ft. to 12 ft. in the eastern ports, from 5½ ft. to 14 ft. in the southern ports and from 3½ ft. to 20 ft. in the western ports. The allowable floor loads range from 600 lb. to 2,000 lb. per sq. ft. and in some cases the loading is unlimited. Berthing depths vary from 6 to 33 ft. and in some instances depths are as great as 42 ft.

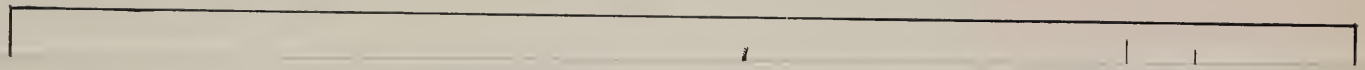
All piers are free of buildings except for towers, trestles, columns and other supports for mechanical conveying systems. Some of the various mechanical systems in use are the traveling steam cranes, car elevators, car dumpers, lorries, cable haul and chutes, conveyors, movable loading towers, traveling bridge cranes, portable conveyors and loading towers with belt conveyors. High trestles are also utilized where coal is unloaded into hoppers and delivered by chutes to vessels.

Ports on the Great Lakes

Coal piers at ports on the American side of the lakes are used principally for the transfer of coal from storage and cars to vessels. Bunker coal is also loaded on vessels. In the Canadian ports the piers are designed principally for transferring coal from vessels to storage and cars. Vessels handling coal are mostly in the lakes trade and in practically all instances coal is handled as a return cargo from American ports. The coal piers in this region are generally bulkheads with earth fill. In some cases steel and timber piling are used with concrete walls and earth fill; also timber decks on wood piles.

The piers range from 260 to 2,200 ft. in length and 22 to 120 ft. in width and where bulkhead construction is used they vary in length from 260 to 4,000 ft. Decks range from 5 to 12 ft. above low water. In Toledo, Ohio, a two-car dumper pier 290 ft. in width was constructed. Piers and bulkheads generally are free from buildings except for the mechanical conveying systems. The allowable floor loads vary from 100 to 1,000 lb. per sq. ft.; and in Buffalo, N. Y., there are piers with capacity unlimited. Berthing depths range from 11 to 23 ft.

The charging and discharging systems are electrically and steam operated. They consist of chain-belt conveyors, car dumpers, bucket conveyors, car tipples, scraper conveyors, caterpillar cranes, movable locomotive cranes, movable tower cranes and portable bridges. The conveyors have a loading capacity ranging from 500 to 1,200 tons per hour and the dumpers from 800 to 1,600 tons per hour. Tower cranes are used to discharge coal from vessels, the rate of discharge per crane is from 150 to 300 tons per hour depending on the size of the buckets, which range up to 2½ tons capacity. A modern coal pier was constructed by the Wheeling & Lake Erie Railroad in 1937 at Huron, Ohio. This project involved the construction of a steel sheet pile cellular bulkhead, and as its construction is of material interest, it is hereinafter described and the installation is shown in Fig. 2.



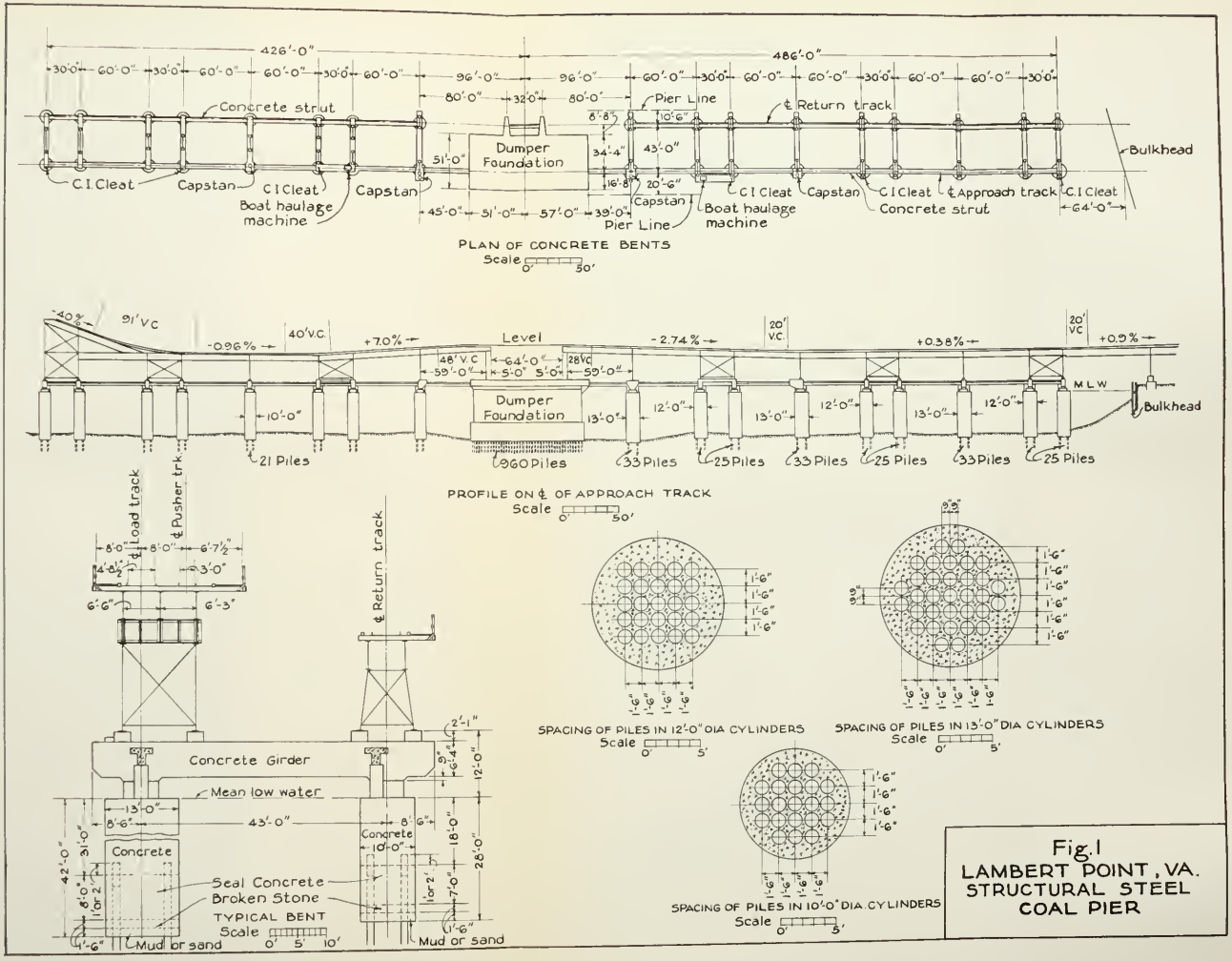
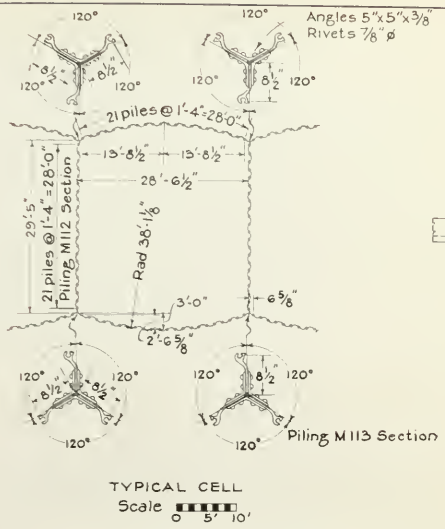
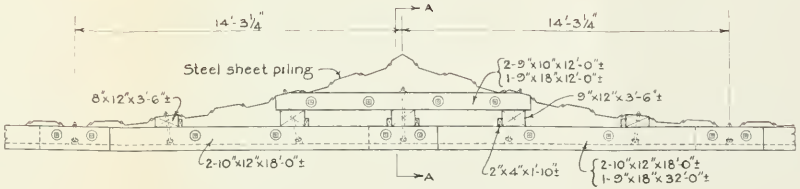


Fig. 1
LAMBERT POINT, VA.
STRUCTURAL STEEL
COAL PIER

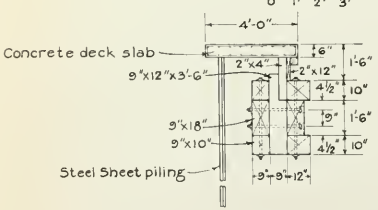
120°
29'-5"
21 piles @ 1'-4" = 28'-0"
120°



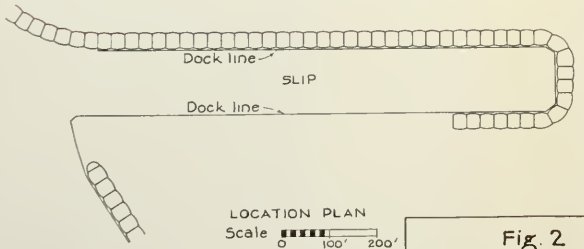
TYPICAL CELL
Scale 0 5' 10'



PARTIAL PLAN OF TYPICAL CELL ON TANGENT
Scale 0 1' 2' 3'



SECTION A-A
Scale 0 1' 2' 3'



LOCATION PLAN
Scale 0 100' 200'

General Notes

Steel Sheet Piling
Interlock tensile strength 12,000 lb per lineal inch.
Standard mill specifications. (With 0.20 per cent copper)
Plain piling to be driven into rock or shale a minimum distance of 12 inches and special piles a distance of 18 inches.
Top of sheet piling to be brought to a uniform grade.
Holes for anchor bolts for fastening timber wales to steel sheet piling to be drilled or burned after piling has been driven.

Concrete Slabs
Slab to be poured in place after the wales have been constructed

Timber
All timber for wales to be of fir and oak and of structural grade. (Rough)
All timber to have two coats of creosote, brushed on after erection.

Fig. 2
HURON, OHIO
STEEL SHEET PILING
CELLULAR BULKHEAD

General

In reviewing the aforementioned reports it is noted that berthing space is not always restricted, being available in many ports to vessels for the entire length of the pier and in some instances on both sides. Where service demands more than one coal pier, the piers are usually located adjacent to one another with a slip between; such slips range from 30 to 260 ft. in width.

Fire prevention and protection is important at every coal pier. This protection consists in some cases of only city service. In addition to this service, fire-boat protection is available in the larger ports. At many coal piers, such service is augmented by booster pumps or by the installation of water pails, portable extinguishers, independent water systems with water tanks, hydrants and hose. In a number of cases a watchman is employed together with manual boxes connected to a city system, and for additional protection, in the event the city system should fail, auxiliary gravity tanks of large capacity with post hydrants have been installed.

The ordinary timber bulkheads range in estimated present cost from $40 per lineal foot for the simplest type of construction to $85 per lineal foot for the more complex type. Where concrete bulkheads are used they are generally of various designs depending upon local conditions and their cost is estimated from $80 to $150 per lineal foot. The common pile and timber pier type is estimated to cost approximately $2.75 per square foot. These costs do not include mechanical facilities required for handling of coal.

The service life of a timber coal pier varies. The portion under water will last indefinitely when not attacked by marine borers, or if necessary preventives are used. The portion above water is estimated to have a normal life of at least 40 years. Where untreated piles decay at the waterline the general practice is to cut them off below the waterline and replace the upper portion with timber bents. In modern practice where creosoted or concrete piles are used, the normal life is estimated to be not less than 40 to 50 years. Mechanical wear is excluded.

No data on the maintenance costs of coal piers were available in the preparation of this report. It is the committee's thought that the maintenance cost should be very similar to the cost of substructure for warehouse piers, excepting mechanical facilities for handling coal.

Pier at Lambert Point, Virginia

The pier at Lambert Point is 1,000 ft. long by 74 ft. wide and it is served by a wide slip dredged to a minimum depth of 38 ft. The dumper is located about 700 ft. from the inshore end and is served by two structural steel viaducts, one for carrying loads to the car dumper and the other for returning the empty cars to the empty car yard. The newly constructed coal pier and dumper is described in detail in "Railway Age" of April 24, 1937. The principal characteristics of the superstructure and the foundations are as follows:

> The pier is built around and is entirely independent of the car dumper foundation and of all of the footings supporting the steel viaducts carrying cars to and from the dumper. The viaduct footings consist of concrete cylinders resting upon clusters of timber piles, while the dumper foundation consists essentially of one large block of concrete, 108 ft. long by 49 ft. wide by 56 ft. deep, resting upon a group of 960 timber piles.
>
> The viaduct footings varying in length from 24 to 45 ft., were constructed within steel shells or cylinders, varying in diameter from 10 to 13 ft. After each steel shell was set in place and driven into the river bottom sufficiently to become self-supporting, the piles were driven inside it, usually to within 8 or 10 ft. of the bottom.

When all of the piling had been driven in a cylinder, the cylinder was pumped free of mud to the original bottom level, exposing the tops of the piles for lengths of 8 to 10 ft. Following this, 2 ft. of broken stone was placed, and then, using a tremie 8 inches in diameter, a seal course of concrete was placed around the piles of sufficient depth to cover them. After this concrete had set, the cylinder was pumped dry and the upper part of the footing was poured.

Placing the huge block of concrete for the dumper footing was considerably more difficult than placing the individual, relatively small viaduct footings. Here, following the dredging of the material in the bottom over the area affected to a level of 43 ft. below mean low water, which involved the removal of approximately 528,000 cu. ft. of sand and silt, a part of the pier pile fender system was driven, and then the 960 foundation piles, 30 to 55 ft. in length, were driven, being followed down to about 31 ft. below water. Upon the completion of the pile foundation, a timber cofferdam framework was floated into place and was anchored to that part of the fender system already driven. This pier, was built in three tiers. When in position the framework was enclosed with interlocking steel sheet piling.

Following the same procedure as with the viaduct footings, all mud and silt were pumped from the cofferdam, and a seal course of concrete, 12 ft. thick was then placed continuously within its confines, about and over the pile heads. The concrete was placed by tremies, working from the four sides of the cofferdam toward the center. This method insured that the best quality of concrete would be placed in the seal about the sides of the cofferdam, and effectively prevented the formation of a laitance crust. When the seal course had been completed and had set up, the cofferdam was pumped dry, and then the upper part of the foundation was placed. Altogether, approximately 6,000 cubic yards of concrete were required in the dumper foundation.

Pier at Huron, Ohio

The site for the coal dumpers at Huron, Ohio, included dredging of the slip and river channel to the depths established by the new rules of the Corps of Engineer, U. S. War Department and the construction of a steel-sheet pile cellular bulkhead. This consists of outer and inner sheet pile walls from 28 to 34 ft. apart connected at intervals of about 28½ ft. by sheet-pile diaphragm walls. These sheet piles for the front and rear walls were driven from 12 to 18 in. into rock so that the piles in the front row, which extend 7 ft. above mean lake level are from 30 to 40 ft. long. Shorter piles were used for the rear wall and the diaphragms, as shown in the sketch. These piles were driven with a 9B3 McKiernan–Terry hammer in leads supported by a locomotive crane. This bulkhead entailed the driving of 1,500 tons of sheet piling exclusive of the piles required for additional bulkhead constructed elsewhere on the dock property.

A distinctive feature of this bulkhead is the ingenious means of insuring a good alinement for the walk and waling timbers that was necessarily supported from the irregular sheet-pile face. This was done by taking measurements to determine the exact dimensions of steel bracket plates at each bracket location along the wall and having them fabricated to fit. They were attached to the sheet piles by welding. The walk, of concrete slabs, has the advantage of greater visibility at night than a walk of darker color.

Conclusion

In reviewing the data on hand, the committee is led to the conclusion that the design of coal piers is more or less individually determined by local requirements, the substructure for which must be planned to meet with local conditions and for loads heavier than is the general practice in the common design of piers.

It is recommended that this report be received as information.

REPORT OF COMMITTEE 9—HIGHWAYS

J. G. Brennan, *Chairman;*
F. D. Batchellor,
Henry A. Bertram,
Harry D. Blake,
H. E. Brink,
S. N. Crowe,
A. T. Danver,
A. R. Dewees,
A. F. Dorley,
W. M. Dunn,
G. N. Edmondson,
C. F. Edwards,
P. W. Elmore,
H. L. Engelhardt,
H. W. Fenno,
D. E. Field,
P. M. Gault,
R. C. Gowdy,
A. S. Haigh,
J. P. Hallihan,
H. A. Hampton,
Wm. J. Hedley,
A. G. Holt,
C. D. Horton,
Maro Johnson,
R. B. Kittredge,
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W. C. Pinschmidt,
T. M. Pittman,
L. J. Riegler,
Frank Ringer,
H. M. Shepard,
C. K. Smith,
Wm. C. Swartout,
C. A. Taylor,
V. R. Walling,
J. L. Way,
J. W. Wheeler,
Leroy Wyant,
W. L. Young,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Economic aspects of grade crossing protection in lieu of grade separation. Progress in study—no report.

3. Design and specifications for highway crossings at grade over railway tracks, both steam and electric, collaborating with Committee 1—Roadway and Ballast, and with American Society of Municipal Engineers, and American Transit Association. Progress in study—no report.

4. Comparative merits of various types of grade crossing protection, collaborating with Committee 10—Signals and Interlocking, Signal section, and Safety section, and Highway Research Board. Progress in study—no report.

5. Develop drawings showing general requirements for installations of automatic gates (Appendix B). Complete with recommended conclusions for publication in the Manual as recommended practice.

6. Method of classifying grade crossings with respect to hazard (Appendix C). Progress in study—no report.

7. Prepare requisites for floodlighting of railroad-highway grade crossings (Appendix D). Complete with recommended conclusions for publication in the Manual.

8. Lamps on manual and automatic crossing gates, collaborating with Signal section (Appendix E). Complete with recommended conclusions for publication in the Manual.

9. Requisites for automatic gates (Appendix F). Complete with recommended conclusions for publication in the Manual.

The Committee on Highways,
J. G. Brennan, *Chairman.*

Bulletin 407, December, 1938.

Appendix A

(1) REVISION OF MANUAL

P. M. Gault, Chairman, Subcommittee; Bernard Blum, H. E. Brink, P. W. Elmore, A. S. Haigh, Maro Johnson, R. B. Kittredge, E. R. Lewis, E. E. Mayo, G. P. Palmer, T. M. Pittman, F. Ringer, H. M. Shepard, C. A. Taylor, J. L. Way, Leroy Wyant, W. L. Young.

Highway Crossing Signs and Signals

Present Form

No mounting is shown for the 50 deg. Reflector Crossing Sign shown in the Manual, Figs. 902 and 903, pp. 9–20, 9–21. No ordering references are shown. The crossbuck is painted black on the back. An intermediate plate is required.

Proposed Form

An additional drawing has been developed entitled "Highway Crossing Sign—50 deg. Reflector Type" showing the sign mounted, together with the "number of tracks sign", on a pipe post with a concrete foundation. The height may be varied as required by local conditions. The drawing bears the AAR Signal section No. 1691A and numbers for ordering parts.

Drawing No. 902 has been revised to show the mounting and complete ordering references, and bears the AAR Signal section number for ready reference and ordering of parts.

Drawing No. 903 has been revised. It shows the crossbuck painted white on the back instead of black. It shows that the intermediate plate is optional. The AAR Signal section number and ordering numbers are shown.

All three drawings indicate that synthetic or vitreous enamel is optional.

Recommendation

The committee recommends the adoption of all three of these drawings and their publication in the Manual in place of Figs. 902 and 903 now in the Manual.

Appendix B

(5) DEVELOP DRAWINGS SHOWING GENERAL REQUIREMENTS FOR INSTALLATIONS OF AUTOMATIC GATES

Maro Johnson, Chairman, Subcommittee; Bernard Blum, A. F. Dorley, H. W. Fenno, P. M. Gault, R. C. Gowdy, H. A. Hampton, W. J. Hedley, A. G. Holt, C. D. Horton, G. A. Knapp, A. E. Korsell, W. C. Pinschmidt, L. J. Riegler, W. C. Swartout, C. A. Taylor, Leroy Wyant.

Drawings showing three typical cases have been developed:

Case I—Right-angle crossing.

Cases II and III—Skew crossings.

Recommendation

The committee recommends the adoption of these three drawings for publication in the Manual.

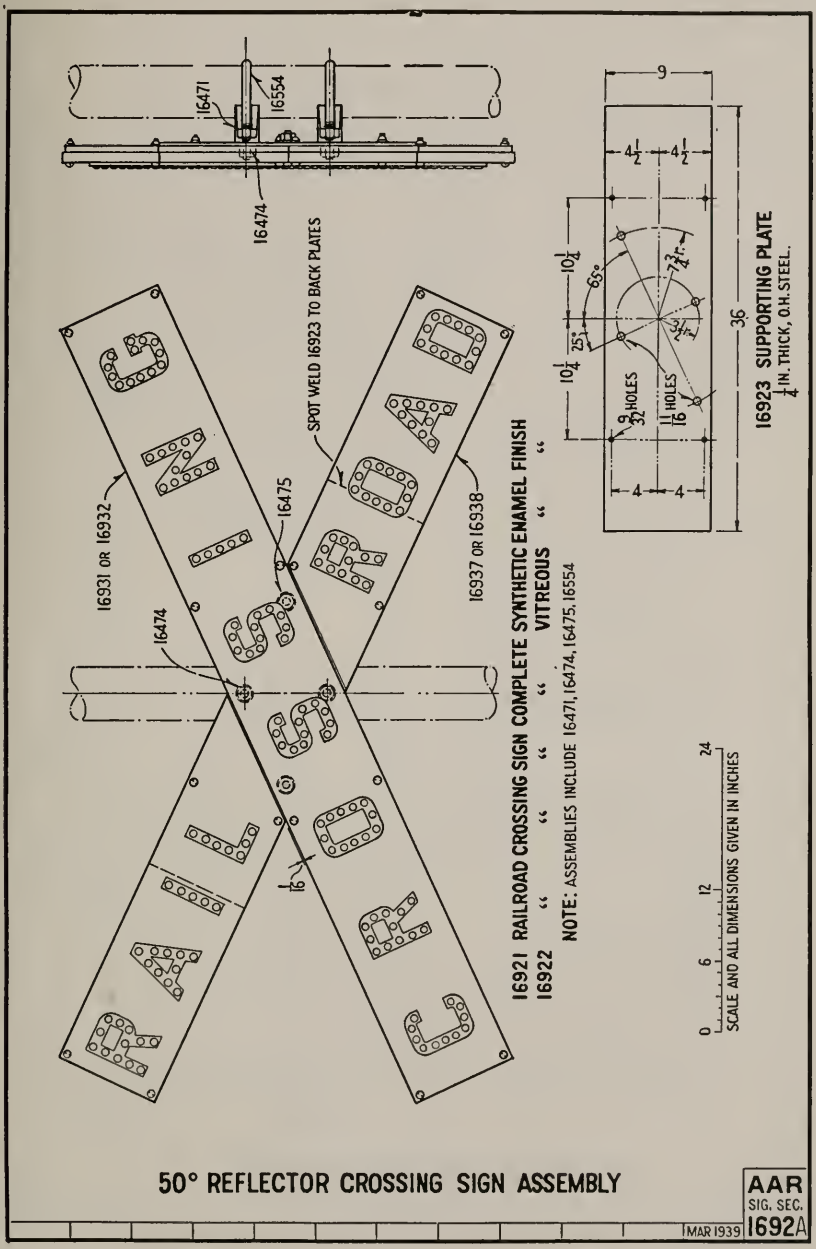


Fig. 902.

Detail Plan of Highway Crossing Sign.
50 Deg. Reflector Type.

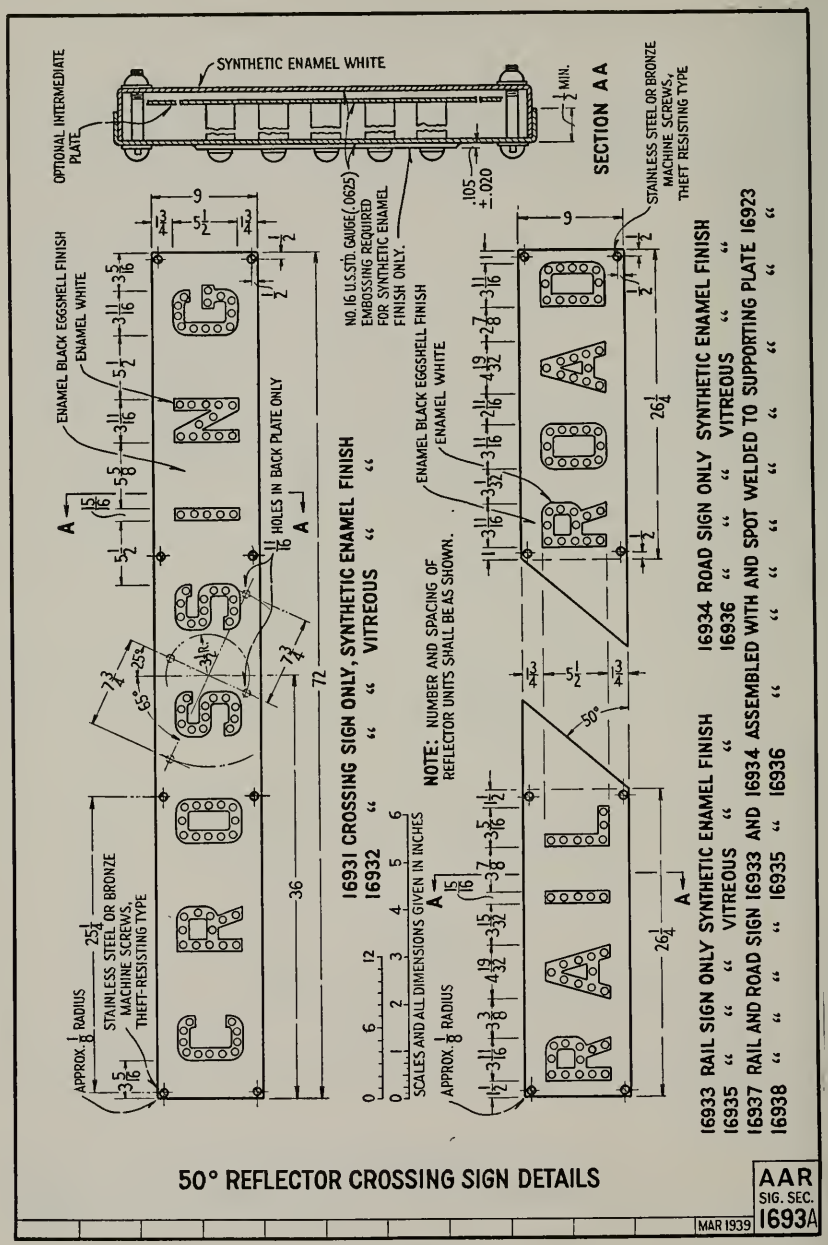

50° REFLECTOR CROSSING SIGN DETAILS
16931 CROSSING SIGN ONLY, SYNTHETIC ENAMEL FINISH
16932 " " VITREOUS " "
16933 RAIL SIGN ONLY SYNTHETIC ENAMEL FINISH
16935 " " VITREOUS " "
16937 RAIL AND ROAD SIGN 16933 AND 16934 ASSEMBLED WITH AND SPOT WELDED TO SUPPORTING PLATE 16923
16938 " " " " 16935 " 16936
16934 ROAD SIGN ONLY SYNTHETIC ENAMEL FINISH
16936 " " " VITREOUS " "
SECTION AA
SYNTHETIC ENAMEL WHITE
OPTIONAL INTERMEDIATE PLATE
ENAMEL BLACK EGGSHELL FINISH
ENAMEL WHITE
HOLES IN BACK PLATE ONLY
NO. 16 U.S.STD. GAUGE (.0625) EMBOSSING REQUIRED FOR SYNTHETIC ENAMEL FINISH ONLY.
STAINLESS STEEL OR BRONZE MACHINE SCREWS, THEFT-RESISTING TYPE
APPROX. 1/8 RADIUS
NOTE: NUMBER AND SPACING OF REFLECTOR UNITS SHALL BE AS SHOWN.
SCALES AND ALL DIMENSIONS GIVEN IN INCHES
AAR SIG. SEC. 1693A
MAR 1939

Fig. 903.

Detail Plan of Highway Crossing Sign.
50 Deg. Reflector Type.

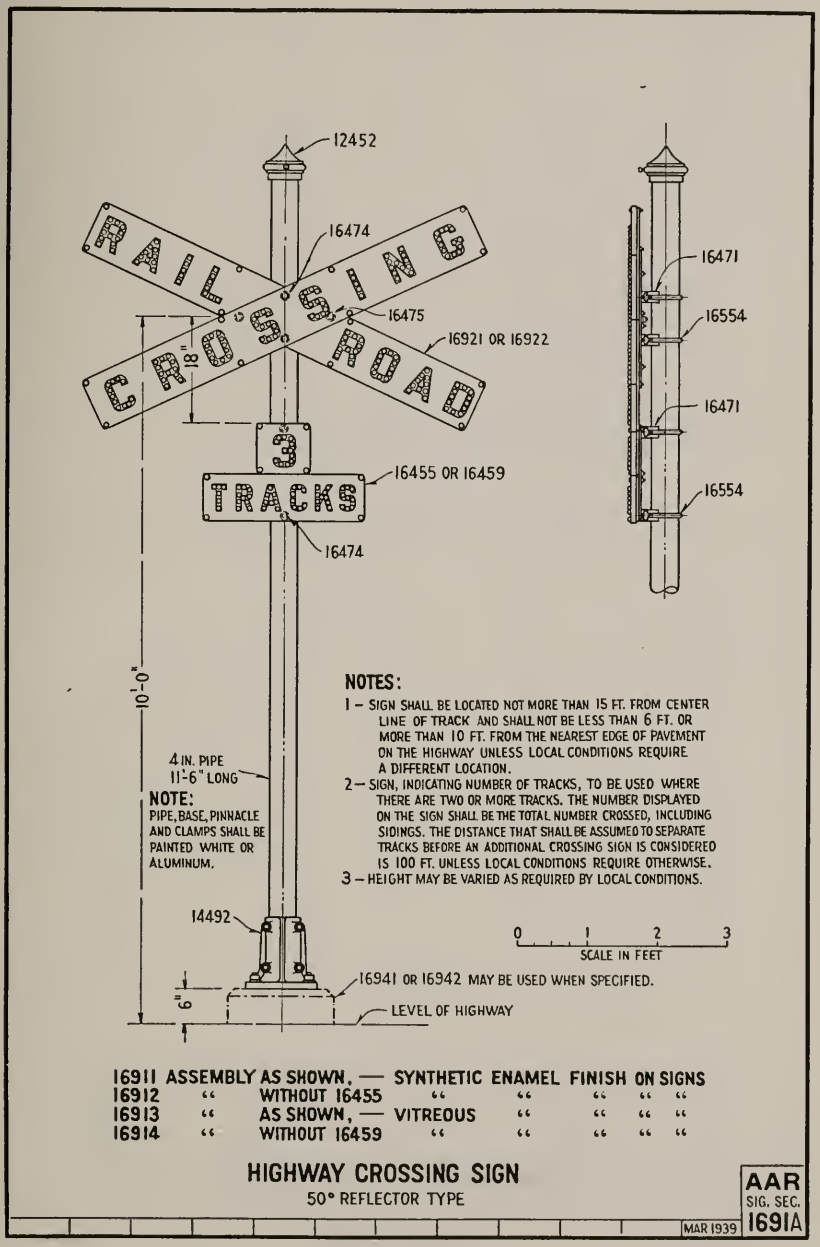
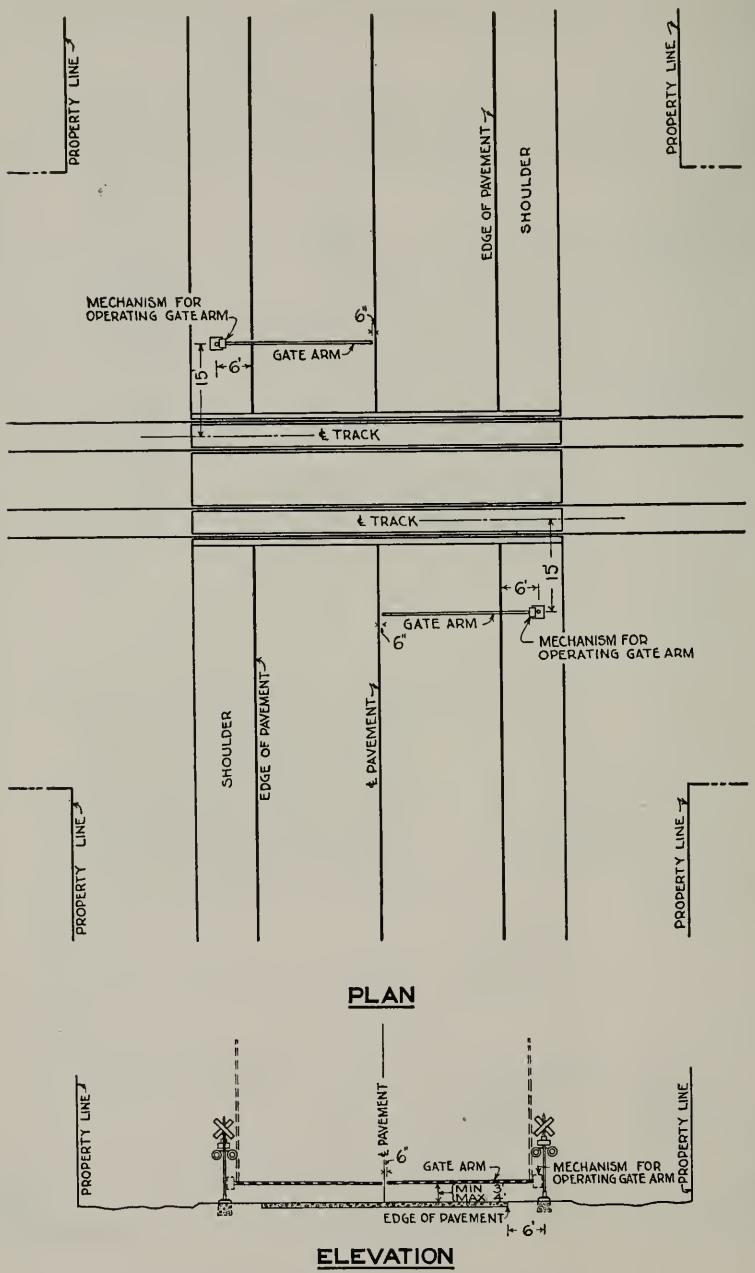
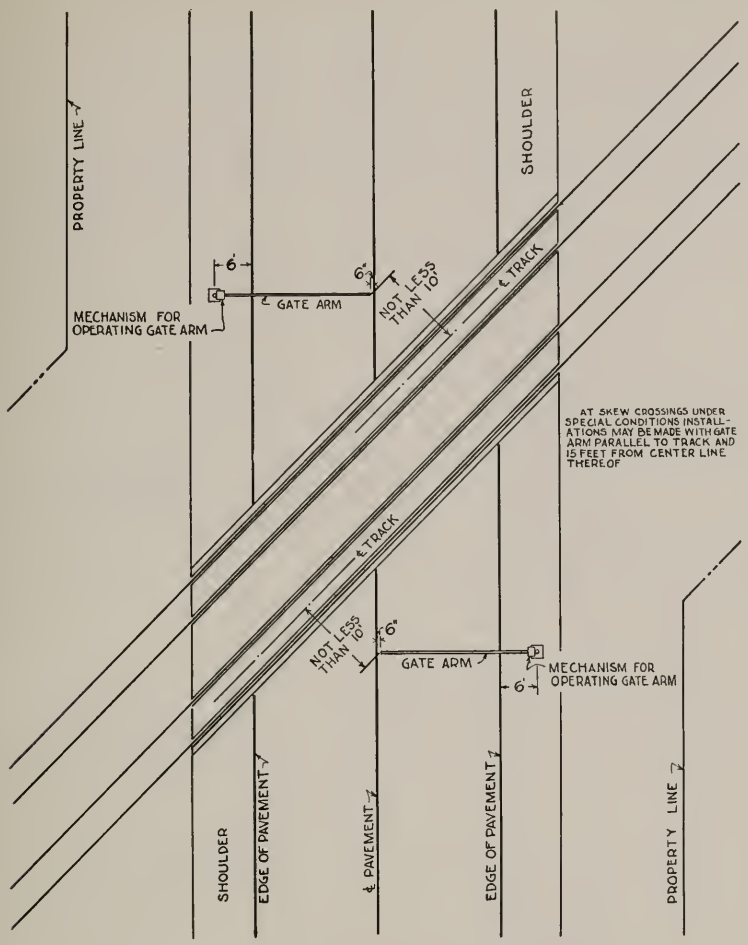

12452
16474
RAILROAD CROSSING
16475
16921 OR 16922
18"
3
TRACKS
16455 OR 16459
16474
16471
16554
16471
16554
10'-0"
4 IN. PIPE
11'-6" LONG
NOTE:
PIPE, BASE, PINNACLE AND CLAMPS SHALL BE PAINTED WHITE OR ALUMINUM.
NOTES:
1 – SIGN SHALL BE LOCATED NOT MORE THAN 15 FT. FROM CENTER LINE OF TRACK AND SHALL NOT BE LESS THAN 6 FT. OR MORE THAN 10 FT. FROM THE NEAREST EDGE OF PAVEMENT ON THE HIGHWAY UNLESS LOCAL CONDITIONS REQUIRE A DIFFERENT LOCATION.
2 – SIGN, INDICATING NUMBER OF TRACKS, TO BE USED WHERE THERE ARE TWO OR MORE TRACKS. THE NUMBER DISPLAYED ON THE SIGN SHALL BE THE TOTAL NUMBER CROSSED, INCLUDING SIDINGS. THE DISTANCE THAT SHALL BE ASSUMED TO SEPARATE TRACKS BEFORE AN ADDITIONAL CROSSING SIGN IS CONSIDERED IS 100 FT. UNLESS LOCAL CONDITIONS REQUIRE OTHERWISE.
3 – HEIGHT MAY BE VARIED AS REQUIRED BY LOCAL CONDITIONS.
14492
0 1 2 3
SCALE IN FEET
6"
16941 OR 16942 MAY BE USED WHEN SPECIFIED.
LEVEL OF HIGHWAY
16911 ASSEMBLY AS SHOWN, — SYNTHETIC ENAMEL FINISH ON SIGNS
16912 " WITHOUT 16455 " " " " "
16913 " AS SHOWN, — VITREOUS " " " "
16914 " WITHOUT 16459 " " " " "
HIGHWAY CROSSING SIGN
50° REFLECTOR TYPE
AAR SIG. SEC. 1691A
MAR 1939

Fig. 903–A.

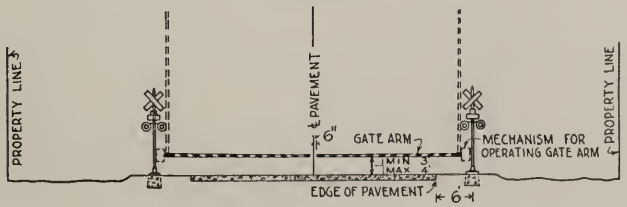
Mounting for Highway Crossing Sign.
50 Deg. Reflector Type.



Typical Location Plan for Automatic Crossing Gates.
Case 1.

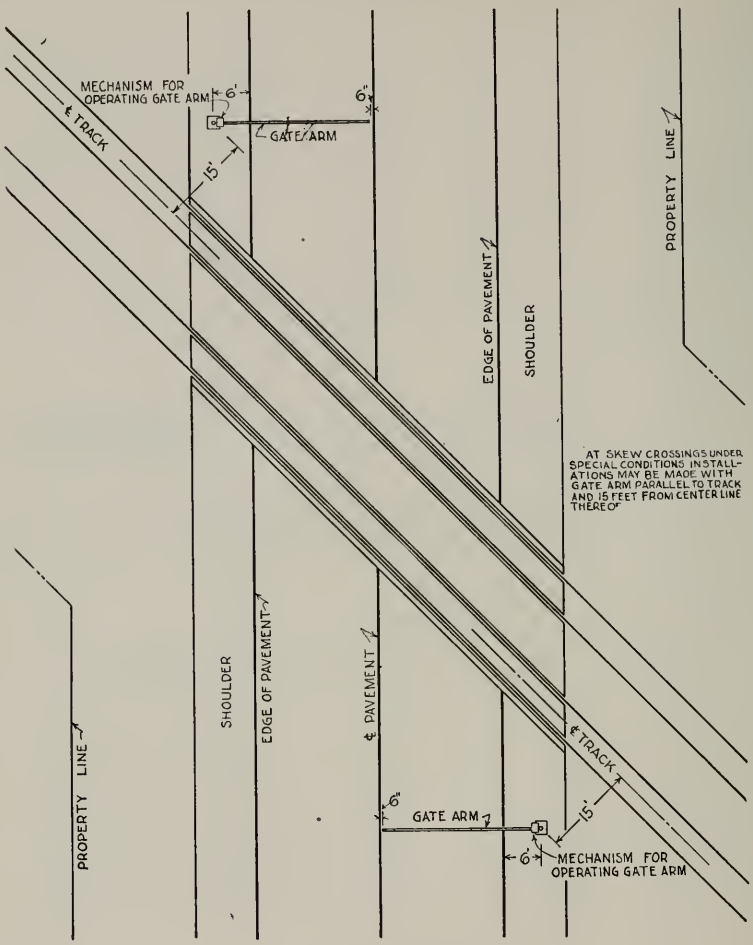


PLAN

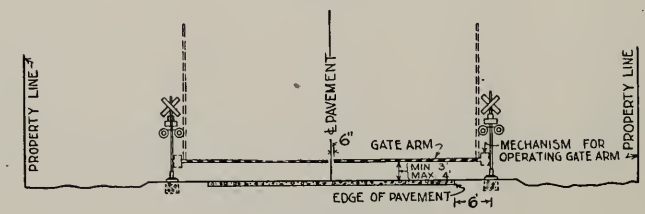


ELEVATION

Typical Location Plan for Automatic Crossing Gates.
Case 2.



PLAN



ELEVATION

Typical Location Plan for Automatic Crossing Gates.
Case 3.

Appendix C

(6) METHOD OF CLASSIFYING GRADE CROSSINGS WITH RESPECT TO HAZARD

E. R. Lewis, Chairman, Subcommittee; F. D. Batchellor, H. A. Bertram, H. D. Blake, A. T. Danver, W. M. Dunn, W. J. Hedley, C. D. Horton, A. E. Korsell, F. Lavis, W. C. Pinschmidt, T. M. Pittman, L. J. Riegler, F. Ringer, C. K. Smith, V. R. Walling, J. W. Wheeler.

Your committee's work this year consisted of the preparing of a list of the chief factors entering into the determination of a method for the classification of crossings as to hazard.

1. General

Classifying as to hazard necessitates analysis of the physical conditions of the crossings and approaches, as well as an analysis of the uses to which the crossings are subjected under the various conditions of traffic on the railroad and highway. While any useful formula intended for wide application must be no more than a general guide, leaving much to the investigator's judgment, the method should be definite enough to present an orderly guidance for the comparison of crossings involving all degrees of hazard, so that any series of crossings may be listed in the order of priority for improvement. The method preferably is selected to apply to all grade crossings, specially protected as well as unprotected, because the existing protection may not presently be suitable on account of changed conditions.

2. Factors

The chief factors of danger comprise, (A) the physical characteristics of the crossing, which factors are classed as constants, and (B) the railway and highway traffic passing over the crossing, which factors are classed as variables, as shown in the following tables. These factors should be given consideration in conjunction with the accident record of the crossing.

TABLE A

Physical Characteristics

1. Angles
   - a. Intersection
   - b. View
2. Highway
   - a. Alinement
   - b. Grades
   - c. Traffic lanes
   - d. Roadway surface
3. Railway
   - a. Alinement
   - b. Grades
   - c. Tracks
4. Obstructions to View
   - a. Total
   - b. Partial
   - c. Fixed
   - d. Seasonal

TABLE B

Traffic Conditions

1. Railway Traffic
   - a. Volume
   - b. Speed
   - c. Character
   - d. Standing cars
2. Railway Traffic
   - a. Volume
   - b. Speed
   - c. Character
   - d. Standing vehicles

*3. Opposing Traffic, Peak Periods
   - a. Day
   - b. Night
   - c. Seasonal
   - d. Special

4. Pedestrian Traffic, Peak Periods
   - a. Day
   - b. Night
   - c. Special

* Opposing—Involved in crossing delays.

5. Environment
   a. Isolated highways
   b. Intersecting streets
   c. Side drives
   d. Nearby, non-intersecting roads and drives

6. Climatic Conditions
   a. Frost
   b. Snow, ice
   c. Fog, darkness
   d. Sun glare
   e. Storms

3. Drawings

Consideration of hazards necessitates a plat of the crossing and vicinity, inclusive of the main physical features within reasonable limits on the approaches by road and rail, as mentioned in the tables. The relative positions of obstructions to sight should be platted in suitable detail. Photographs also are desirable.

It is evident that the speed of highway vehicles and railroad trains governs the orderly movements of opposing traffic over the crossing, and that the distance of the train from the crossing when first observed determines whether the driver may cross in front, or must wait until the train has passed. Such calculations are readily made with the aid of a diagram indicating the relative values of speed, distance, time and safe intervals for crossing.

4. Weights

The weights allocated to the factors govern the ratings. Therefore, special care is suggested in the comparative evaluation of multipliers. Intimate knowledge of traffic variations over individual crossings is important to sound judgment of average use. Climatic conditions likewise have a direct bearing on comparative values as poor to dangerous total driving periods may be experienced on as many as 120 days annually in many of our northerly latitudes and in high altitudes, as against approximately one-tenth of that number in some not distant localities where winter driving conditions are not involved. Extremes of climatic influence exist within the boundaries of any one of a number of the states.

Of the physical characteristics, the angle of intersection is first in basic importance, the ideal angle being 90 deg. Conscious effort on the part of the driver as well as some danger is involved in turning to look far to one side as commonly is necessary to get a clear view of the tracks "behind" while approaching an acute angle crossing. The gradients of grade-crossing approach roads are considered of less importance than approximately level standing spaces for cars between the tops of approach grades and the tracks.

The value of the formula will depend on accuracy in allocating factor weightings, on simplicity of the method selected and on judgment in handling unusual peculiarities of individual cases. It must be remembered that many crossing accidents are due wholly to the personal element.

Progress report offered as information.

Appendix D

(7) PREPARE REQUISITES FOR FLOODLIGHTING OF RAILROAD-HIGHWAY GRADE CROSSINGS

C. A. Taylor, Chairman, Subcommittee; H. E. Brink, A. R. Dewees, G. N. Edmondson, H. L. Engelhardt, P. M. Gault, A. S. Haigh, H. A. Hampton, G. A. Knapp, E. E. Mayo, G. P. Palmer L. J. Riegler, W. C. Swartout, W. L. Young.

REQUISITES FOR FLOODLIGHTING OF RAILROAD-HIGHWAY GRADE CROSSINGS

1. Floodlighting may be provided at crossings which are blocked an appreciable amount of time by moving trains or standing cars, or where the gradient of the approaches is such that the headlights of an oncoming vehicle shine over or under the railroad cars, or where other conditions result in low visibility at night. Preference shall be given to locations which are not otherwise protected by manual or automatic devices.

2. Floodlighting shall be used only where reliable a. c. power is available at the crossing.

3. The light used shall have a beam of sufficient intensity to illuminate clearly any type of railroad equipment that is standing on or passing over the crossing.

4. The illumination of the railroad equipment obstructing the crossing shall be visible to the user of the highway, with normal vision, for a distance of at least 500 feet in clear weather where there is no obstruction to the view of the crossing.

5. Both sides of the railroad equipment occupying the crossing shall be illuminated.

6. A minimum of one light shall be provided on each side of the tracks, and additional lights shall be provided where necessary for complete illumination of the railroad equipment occupying the crossing.

7. Where only one light is used on each side of the tracks, provision shall be made for automatically cutting in another lamp or lamp filament in case of a burnout. Where a two-filament lamp is used a visual indication of filament burnout shall be provided.

8. The lights should be placed on poles located preferably to the left of the highway approaching the crossing. The poles shall be located from 25 to 50 feet from the nearest track and a minimum of 8 feet from the shoulder of the highway.

9. The height of the lights above the top of the rail shall be such as to provide the best illumination of the railroad equipment. The height may vary from 20 to 30 feet, depending upon local conditions.

10. The lights shall be arranged so that the glare will not be excessive either along the highway or railroad.

11. The illumination of continuously lighted crossings preferably shall be distinctive in volume, distribution, or color from ordinary street or other lighting so as to attract the motorist's attention.

12. Floodlighting at crossings may, where practicable, be automatically controlled by track circuits. The track circuits shall be of sufficient length to insure the crossing being illuminated for not less than 20 seconds before the arrival of the fastest train operating over the crossing.

13. Circuits for automatic control of floodlighting shall be so arranged that the lights will burn until the rear end of the railroad equipment has cleared the crossing.

14. Where automatic control of floodlighting is used the type of light shall be such as to give full illumination immediately upon energy being applied.

15. The illumination shall be continuous where rail traffic is heavy or where there is a considerable amount of night switching.

16. Arrangements should be made to prevent lights from burning in the daytime when protection is not required. This may be accomplished manually or automatically as desired.

Recommendation

Recommended for inclusion in the Manual.

Appendix E

(8) LAMPS ON MANUAL AND AUTOMATIC CROSSING GATES, COLLABORATING WITH SIGNAL SECTION

W. L. Young, Chairman, Subcommittee; H. D. Blake, A. F. Dorley, C. F. Edwards, P. W. Elmore, H. L. Engelhardt, D. E. Field, A. S. Haigh, H. A. Hampton, A. G. Holt, C. D. Horton, G. A. Knapp, E. E. Mayo, T. M. Pittman, J. L. Way, Leroy Wyant.

Manually Operated Crossing Gates

1. On manually operated crossing gates one or more lamps shall be provided on each gate arm, facing the highway for night indication only, so arranged, as far as practicable, as not to be visible from the track.

2. Oil lamps, when used, shall be in accordance with Signal section, AAR drawings 1497, 1498 and 1499.

3. Electric lighting may be provided for manually operated crossing gates where reliable A.C. power is available at the crossing.

4. Electric lamps, when used, shall be arranged to light when the gate arm starts to lower and remain lighted until the gate arm returns to the open position.

5. Electric lamps and operating mechanism shall be in accordance with specifications prepared by the Signal section.

Automatic Crossing Gates

6. Automatic crossing gate arms extending over the roadway shall be equipped with two red electric lamps for each lane of traffic.

7. The lamps shall shine in both directions along the highway for night indication only.

8. Lamps shall burn continuously except when gate arms are in the raised position, and shall be shielded as far as practicable to prevent shining along the track.

9. The design of the lamp unit and the operating mechanism shall be in accordance with specifications prepared by the Signal section.

The subcommittee recommends that this report be received as information until such time as a satisfactory specification for the electric lamp unit has been worked out by the Signal section.

Appendix F

(9) REQUISITES FOR AUTOMATIC CROSSING GATES

Bernard Blum, Chairman, Subcommittee; G. P. Palmer, J. G. Brennan.

Last year Committee 9 developed requisites for automatic crossing gates which were approved for inclusion in the Manual at the 1938 convention. A committee of the Signal section in collaboration developed identical requisites, but these were not approved by the

Signal section at its convention last year. It was therefore decided not to publish the requisites in the AREA Manual until further collaboration had been had. After collaboration with a subcommittee of the Signal section, Committee 9 again presents requisites for automatic gates.

1. Automatic gates where installed shall be provided as an adjunct to AAR recommended automatic crossing signals of the flashing light or wigwag types.

2. Automatic gates for the protection of highway traffic at a railroad grade crossing, shall, when indicating the approach of a train, present toward the highway the appearance of a horizontal arm extending over the traveled roadway a sufficient distance to cover the lane or lanes used by traffic approaching the crossing.

3. The automatic gate arms when not indicating the approach of a train shall not obstruct or interfere with highway traffic.

4. A highway crossing bell, if used, shall sound a warning while the gate is being lowered.

5. The automatic gate arms shall be mounted on posts or housings containing the arm operating mechanisms.

6. The design of the gate operating mechanism shall, as far as practicable, be such as to insure proper operation during unfavorable weather conditions, and if out of order, the gate arms shall assume the horizontal position across the roadway.

7. The mechanisms shall be so designed that if the arms, while being raised or lowered, strike or foul an object, they will readily stop and, on removal of the obstruction, shall assume the position corresponding with the control apparatus.

8. Circuits for the operation of the automatic gates shall be so arranged that gates will start to assume the horizontal position between 3 and 5 seconds after the warning signals start to operate. Gates shall reach full horizontal position before the arrival of the fastest train operated over the crossing and shall remain down until the rear of the train has cleared the crossing.

9. Each gate arm, extending over the roadway, shall have 2 red lights, for each lane of traffic it protects, shining in both directions along the highway for night indication.

10. The bottom of gate arms, when in the horizontal position, shall be not less than 3 nor more than 4 feet above the crown of the roadway.

11. The gate arms shall be painted on both sides with alternate diagonal stripes of white and black.

12. The automatic highway crossing signals shall operate in accordance with AAR recommended practice and independently of the gates.

13. Details of the signals, gates, operating mechanisms, and control circuits shall be in accordance with AAR recommended practice.

14. The gate arms shall operate uniformly, smoothly and complete all movements without rebound or slap, and be securely held when in the raised position.

15. Each individual gate post shall be provided with an independent operating mechanism, and housing to be of sufficient size to allow ready inspection, adjustment and repairs.

16. The lights on the gate arms shall burn continuously except when the arms are in the raised position.

17. The highway traffic lanes in the vicinity of the crossing shall be distinctly marked.

Recommendation

Recommended for adoption and publication in the Manual.

REPORT OF COMMITTEE 27—MAINTENANCE OF WAY WORK EQUIPMENT

G. R. Westcott, *Chairman;*
C. M. Angel,
C. T. Blume,
G. E. Boyd,
W. O. Cudworth,
J. R. Derrick,
J. T. Derrig,
J. F. Donovan,
C. R. Edwards,
G. J. Ermentrout,
Robert Faries,
C. L. Fero,
Paul Hamilton,
J. G. Hartley,
C. E. Herth,
L. B. Holt,
J. S. Huntoon,
N. W. Hutchison,
E. C. Jackson,
R. K. Johnson,
C. R. Knowles,
Jack Largent,
E. H. Mills,
C. E. Morgan,
R. A. Morrison,
C. H. Morse,
C. H. R. Howe, *Vice-Chairman;*
A. J. Neff,
E. H. Ness,
C. H. Ordas,
E. Pharand,
T. M. Pittman,
E. L. Potarf,
F. H. Rothe,
J. C. Ryan,
J. G. Sheldrick,
R. P. Winton,
F. F. Zavatkay,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual. Progress in study—no report.

2. Standardization of parts and accessories for railway maintenance motor cars. Progress in study—no report.

3. Depreciation of work equipment, collaborating with Committee 11—Records and Accounts (Appendix A). Complete and presented as information.

4. Self-contained direct-blow gasoline tampers. Progress in study—no report.

5. Concrete vibrators, collaborating with Committee 8—Masonry. Progress in study—no report.

6. Methods of keeping data on work equipment (Appendix B). Presented as information.

7. Scheduling the use for work equipment (Appendix C). Complete and presented as information.

8. Sand blasting equipment. Progress in study—no report.

9. Track welding equipment.

   (a) Oxy-acetylene. Progress in study—no report.

   (b) Electric arc, collaborating with Committee 5—Track. Progress in study—no report.

10. Railway owned automotive equipment, collaborating with Committee 13—Water Service, Fire Protection and Sanitation (Appendix D). Presented as information.

11. Rail saws (Appendix E). Complete and presented as information.

12. Power tools for bridge maintenance (Appendix F). Complete and presented as information.

13. Safety devices for work equipment, collaborating with Committee 22—Economics of Railway Labor. Progress in study—no report.

The Committee on Maintenance of Way Work Equipment,
G. R. Westcott, *Chairman.*

Bulletin 407, December, 1938.

Appendix A

(3) DEPRECIATION OF WORK EQUIPMENT

Collaborating with Committee 11—Records and Accounts

C. H. R. Howe, Chairman, Subcommittee; J. T. Derrig, C. R. Edwards, Paul Hamilton, J. S. Huntoon, C. R. Knowles, R. A. Morrison, C. H. Morse, J. G. Sheldrick.

Your committee has made further study of this subject during the year, and is now of the opinion that further developments are contingent on the establishment of factual data concerning the service life of roadway equipment. As it will necessarily require a number of years to secure this information, the committee sees no advantage to be gained by further present discussion.

Appendix B

(6) METHODS OF KEEPING DATA ON WORK EQUIPMENT

N. W. Hutchison, Chairman, Subcommittee; J. T. Derrig, J. F. Donovan, G. J. Ermentrout, Paul Hamilton, C. E. Herth, E. H. Mills, J. G. Sheldrick.

The selection, purchase and subsequent utilization of work equipment is obviously a problem of securing an adequate return on the investment made. While it is true that initial tests of a new machine may be conducted, in order to determine its productive capacity and to judge its efficiency and economy temporarily, as compared with other machines and other methods, such tests furnish no definite clue as to the maintenance costs to be incurred. It is, therefore, desirable to maintain records for a period sufficiently long to establish such facts as may be essential in governing further investment.

The decision as to whether such records shall be maintained, the nature and the extent of the data to be recorded and the design of the forms to be used, rests entirely with the responsible officers of each individual railroad. Consequently, the forms designed for, and published as part of this report, are presented, not with the idea of securing adoption of them as standard but merely to assist those who are interested in, but unfamiliar with, methods and forms now in use.

Replies to requests for forms in use permitted the study of approximately 125 forms of various descriptions, most of which are similar in purpose but dissimilar as to the type of information desired. The forms here presented are based upon the information desired by the majority of the railroad officers who replied.

Certain forms, general in nature, may be used for all types and classes of machines; other forms, also general in nature, may be used for certain groups, types and classes; still other forms, specific in nature, are applicable to but one type of machine. Your committee formed the opinion that, due to a wide variety in the types of machines involved, the report this year should be confined to one selected group, namely motor cars. In view of their wide-spread use and the fact that they are used chiefly as media of transportation rather than for the performance of productive work, it was considered desirable to segregate them from other groups of work equipment.

An outline of the forms presented, with a brief explanation of their purpose follows:

Form 1—*Motor Car Inspection Report*—This form provides for periodic reports relative to the condition of each car, from which, in conjunction with a knowledge of operating and maintenance costs, decisions may be made to justify repairs or replacement.

THE NORTH AND SOUTH RAILROAD MOTOR CAR INSPECTION REPORT

R.R.CAR NO._____ MFRS. SERIAL NO._____ MFR._____

TYPE OF CAR_____ CLASS OF SERVICE_____ ENG. SERIAL NO._____

ASSIGNED TO_____ HEADQUARTERS_____

ITEMS INSPECTED	CONDITION			EST. COST OF REPAIRS			REMARKS
	GOOD	FAIR	REPAIRS	MATERIAL	LABOR	TOTAL	
Body							
Wheels							
Axles and Bearings							
Belt and Fastenings							
Spark Coils							
Batteries							
Wiring							
Switches							
Timer							
Timer Chain							
Timer Gears							
Spark Plugs							
Magneto							
Tank and Connections							
Connecting Rod & Bearings							
Pistons, Rings and Pins.							
Cylinders							
Valves							
Carburetor							
Cam Shaft and Bearings							
Main Bearings							
Axle and Crank							
Crank Case							
Lubrication							
Fly Wheel							
Safety Railing							
Wheel Gauge							
Bolts							
Compression							
Brakes							
Paint							
General Condition							
Total							

INSPECTED BY_____ DATE_____
(Name and Title)

RECOMMEND CAR BE REPAIRED / SCRAPPED _____
(Name and Title)

APPROVED _____
(Name and Title)

FORM NO. 1.—Recommended Size 8½-in. by 11-in.

Form 2—*Monthly Report of Motor Car Operation*—This form, properly filled in, furnishes all essential data covering operating costs and field repairs.

Form 3—*Monthly Report of Shop Repairs to Motor Cars*—This report, in conjunction with Form 2, furnishes all essential operating and maintenance data for each motor car.

THE NORTH AND SOUTH RAILROAD
MONTHLY REPORT OF MOTOR CAR OPERATION

MONTH OF _____ 19__ R.R.CAR NO. _____ MAKE _____

DIVISION _____ SEC.NO OR FORCE _____ HEADQUARTERS _____

LENGTH OF TERRITORY _____ (Miles of Road) A.V.G. NO. OF MEN IN FORCE _____

1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	MILES OPERATED	FUEL AND SUPPLIES USED								FIELD REPAIRS		REMARKS
		GALS. GAS	PTS. OIL	KIND OF OIL	LBS. CUP GREASE	NO OF SPARK PLUGS	NO OF BATT ERIES	MISC. SUPPLIES KIND	MISC. SUPPLIES COST	LABOR MAN HRS.	APPROX MATL. COST	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
TOTAL												

Current cost of gasoline $____ (gal.), oil $____ (pt.), cup grease $____ (lb), spark plugs $____ (ea), batteries $____ (ea)

Correct _____ (Foreman or Car Operator) Approved _____ (Division Engineer)

Instructions:
Under "Remarks" show reason for car being out of service, date sent to and received from shop, etc. "Miles Operated" must be recorded each day; information in columns 3 to 12 incl. must be recorded as supplies are used or repairs are made. Repairs should include only those made by operator or force using car.
Report must be totaled at end of month by operator or foreman, forwarded to Division Engineer who shall insert current cost of supplies, sign and forward to Engr. Maint. of Way.

FORM No. 2.—Recommended Size 8½-in. by 11-in.

Form 4—*Report of Motor Cars Received and Shipped*—This report, furnished immediately upon the receipt or shipment of a motor car, provides ready reference as to its location.

Note: The above two forms, 3 and 4, although designed specifically for reporting motor cars, may also be utilized for other machines by changes of titles and other minor changes in columnar headings.

THE NORTH AND SOUTH RAILROAD
MONTHLY REPORT OF SHOP REPAIRS TO MOTOR CARS

SHOP AT _____ (Location) MONTH OF _____ 19____

R.R. CAR NO.	DATE RCD. AT SHOP	BILLED FROM	DATE SHIPT. FROM SHOP	BILLED TO	COST OF REPAIRS MATERIAL	COST OF REPAIRS LABOR	SHOP ORD. NO.	REMARKS

SIGNED _____ Shop Supt. or Division Mechanic.

Form No. 3.—Recommended Size 8½-in. by 11-in.

THE NORTH AND SOUTH RAILROAD

REPORT OF MOTOR CARS RECEIVED AND SHIPPED

R.R. CAR NO.	MANUFACTURER	TYPE	MFR'S. SER. NO.	MAKE OF ENG.	ENG. SER. NO.	DATE RECD. OR SHIPT.	RECEIVED FROM OR SHIPPED TO

THE ABOVE CAR WAS / CARS WERE TRANS. UPON AUTHORITY OF _____

AND FOR THE PURPOSE OF _____

FOREMAN OR CAR OPERATOR _____ DATE _____ LOCATION _____

UPON RECEIPT OF NEW CAR, INFORMATION SHOWN BELOW MUST BE FURNISHED:

MANUFACTURER _____ TYPE _____ MFR'S. SERIAL NO. _____

MAKE OF ENGINE _____ ENG. SERIAL NO. _____ H.P. _____ NO. OF CYL'S. _____

WEIGHT _____ CAPACITY (MEN) _____ FORCE TO WHICH ASSIGNED _____

DIVISION OR DEPARTMENT _____ HEADQUARTERS _____

PUT IN SERVICE AT _____ (Location) ON _____ (Date) REPLACED CAR NO. _____

Form No. 4.—Recommended Size 8½-in. by 11-in.

THE NORTH AND SOUTH RAILROAD
RECORD OF MOTOR CARS

R.R.CAR NO.____

MANUFACTURER_____ TYPE_____ MFRS. SER. NO._____ MAKE OF ENG._____
ENG. SER. NO._____ H.P._____ CYLS._____ WT._____ CAPY. (MEN)_____ DATE PURCHASED_____
A.F.E. REQN. OR P-ORDER NO._____ ASSIGNED TO_____ DIV. OR DEPT._____
HDQTRS._____ DATE RETIRED OR REPLACED_____ REPLACED BY CAR NO._____

TRANSFERS

FROM	TO	DATE	REASON	FROM	TO	DATE	REASON

SERVICE RECORD

YEAR 19__	SERVICE		FUEL AND SUPPLIES						REPAIR COST	
	MILES	DAYS	GASOLINE		OIL		MISC.		FIELD	SHOP
			GALS	COST	PTS.	COST	COST			
Jan.										
Feb.										
Mar.										
Apr.										
May										
June										
July										
Aug.										
Sept.										
Oct.										
Nov.										
Dec.										
Total										
To Date										

YEAR 19__	SERVICE		FUEL AND SUPPLIES						REPAIR COST	
	MILES	DAYS	GASOLINE		OIL		MISCL.		FIELD	SHOP
			GALS	COST	PTS.	COST	COST			
Jan.										
Feb.										
Mar.										
Apr.										
May										
June										
July										
Aug.										
Sept.										
Oct.										
Nov.										
Dec.										
Total										
To Date										

YEAR 19__	SERVICE		FUEL AND SUPPLIES						REPAIR COST	
	MILES	DAYS	GASOLINE		OIL		MISCL.		FIELD	SHOP
			GALS	COST	PTS.	COST	COST			
Jan.										
Feb.										
Mar.										
Apr.										
May										
June										
July										
Aug.										
Sept.										
Oct.										
Nov.										
Dec.										
Total										
To Date										

FRONT

FORM NO. 5.—Recommended Size 9-in. by 12-in.

Form 5 and Form 6—*Record of Motor Cars*—These two forms provide a permanent record of identifying information and of data obtained through the use of Forms 2, 3, and 4. Form 5 is designed for the use of those desiring detailed records of operating and maintenance costs, whereas Form 6 is designed for the use of those who are interested only in the record of identifying information and location.

SERVICE RECORD

R.R. CAR NO.

YEAR 19__	SERVICE	FUEL AND SUPPLIES				REPAIR COST	
	MILES	DAYS	GASOLINE	OIL	MISC.	FIELD	SHOP
			GALS	PTS.	COST	COST	
Jan.							
Feb.							
Mar.							
Apr.							
May							
June							
July							
Aug.							
Sept.							
Oct.							
Nov.							
Dec.							
Total							
To Date							

YEAR 19__	SERVICE	FUEL AND SUPPLIES				REPAIR COST	
	MILES	DAYS	GASOLINE	OIL	MISC.	FIELD	SHOP
			GALS	PTS.	COST	COST	
Jan.							
Feb.							
Mar.							
Apr.							
May							
June							
July							
Aug.							
Sept.							
Oct.							
Nov.							
Dec.							
Total							
To Date							

YEAR 19__	SERVICE	FUEL AND SUPPLIES				REPAIR COST	
	MILES	DAYS	GASOLINE	OIL	MISC.	FIELD	SHOP
			GALS	PTS.	COST	COST	
Jan.							
Feb.							
Mar.							
Apr.							
May							
June							
July							
Aug.							
Sept.							
Oct.							
Nov.							
Dec.							
Total							
To Date							

YEAR 19__	SERVICE	FUEL AND SUPPLIES				REPAIR COST	
	MILES	DAYS	GASOLINE	OIL	MISC.	FIELD	SHOP
			GALS	PTS.	COST	COST	
Jan.							
Feb.							
Mar.							
Apr.							
May							
June							
July							
Aug.							
Sept.							
Oct.							
Nov.							
Dec.							
Total							
To Date							

BACK

FORM NO. 5.—Recommended Size 9-in. by 12-in.

Conclusion

It is desirable to maintain records relative to the use of work equipment, the nature and extent of which are dependent upon the wishes of the responsible officers of each individual railroad.

This report is presented as information.

A

DIVISION_____ R.R. CAR NO._____

THE NORTH AND SOUTH RAILROAD

RECORD OF MOTOR CARS

MANUFACTURER_____ TYPE_____

MFRS. SERIAL NO._____ MAKE OF ENGINE_____

ENGINE SERIAL NO._____ ENG. H.P._____ NO. OF CYLINDERS_____

WEIGHT OF CAR_____ CAPACITY (MEN)_____ DATE PUR._____

A.F.E., REQN., OR P-ORDER NO._____ ASSIGNED TO_____

DEPARTMENT_____ HEADQUARTERS_____

DATE RETIRED OR REPLACED_____ REPLACED BY CAR NO._____

FRONT

TRANSFERS

FROM	TO	DATE	REASON

BACK

FORM NO. 6.—Recommended Size 4-in. by 6-in.

Appendix C

(7) SCHEDULING THE USE OF WORK EQUIPMENT

C. E. Morgan, Chairman, Subcommittee; J. R. Derrick, Robert Faries, Paul Hamilton, J. G. Hartley, C. E. Herth, N. W. Hutchison, R. A. Morrison, E. Pharand.

Scheduling the use of work equipment in order to secure more working days' output from those machines is necessary if full utilization is to be made of the money invested in that equipment. More people are becoming conscious of the extreme importance of securing both the best possible quality of output as well as the lowest unit cost for such work.

The following work is typical of the operations that may be successfully scheduled:

Distributing rail	Bank widening
Laying rail	Welding rail ends
Picking up rail	Heat treating rail ends
Changing angle bars	Renewing ties
Tightening bolts	Bonding rail
Ballasting track	Burning weeds
Ballast cleaning	Spraying weeds
Ditching	Scarifying
Pile driving	Discing

Many different systems of handling the work equipment are in use on the railroads, some of which place all the authority in a central office while others have each division handle all its own equipment. In order to get a summary of how it is thought best to realize the most use of the work equipment, a questionnaire was sent to the members of this committee asking them to list under the headings System, Region, Division or Supervisor, how various machines should be assigned. The ideas of 20 men representing 16 roads, aggregating about 99,000 miles of railroad, are shown in the table, the figure in each column indicating the number of men believing that the machine in question should be assigned to the terrritory shown at the head of the column.

Tabulation of Number of Preferences for Each Plan of Assignment

Type of Machine	*System*	*Region*	*Division*	*Supervisor*
Rail layers	8	4	6	2
Rail distributing or pick-up outfits	8	5	4	1
Rail loaders	5	5	7	2
Gas welding equipment	5	4	9	3
Arc welding equipment	8	7	5	0
Rail grinding equipment	5	9	7	1
Locomotive cranes	5	6	10	1
Pile drivers	6	8	6	1
Tie tamping outfits	5	1	10	6
Crawler shovels and drag lines	6	8	6	0
Ditchers, top car	3	12	4	0
Ditchers, Jordan	4	12	3	0
Motor cars, section	3	0	4	15
Motor cars, inspection	4	3	8	6
Motor cars, heavy duty	4	0	8	8
Weed mowers	6	5	6	1
Weed burners	5	10	3	0
Weed sprayers	7	9	3	0
Power rail drills	2	4	10	3
Rail adzing machines	7	7	4	0
Spike pullers	8	7	3	0
Power jacks	9	9	0	0
Ballast cleaners	8	8	2	1

Type of Machine	*System*	*Region*	*Division*	*Supervisor*
Power track wrenches	7	3	10	1
Snow plows, wedge	4	4	9	0
Snow plows, rotary	5	7	7	0
Snow plows, side	5	4	7	0
Snow cut wideners	5	6	6	0
Hoisting engines	5	6	8	0
Power winches	5	5	7	2
Rail expansion pullers	3	2	6	7
Electric generating plants	7	4	7	2
Paint spray machines	4	1	12	2
Air compressors	3	5	9	3
Concrete vibrators	5	8	5	2
Concrete mixers	5	4	7	4
Concrete busters	4	4	11	1
Wrecking locomotive cranes	4	3	11	1
Stiff-leg derricks	5	5	16	2
Discing machines	4	5	7	1
Spike drivers	8	7	3	0
Full rail oiling machines	10	5	0	1
Joint oiling machines	5	8	0	3
Tractors	4	7	8	2
Automobiles	3	2	12	5
Trucks	3	1	13	3

It will be noted that there is quite a diversity of opinion as to how the machines should be assigned. This can be explained by the different conditions affecting the work to be done. Among these will be found (a) organization, both of gangs and supervisory forces; (b) climatic conditions; and (c) extent to which the road is mechanized.

The procedure and the results that may be expected, as set up in the detailed discussion below, are based on the practice of one large railroad, quite fully mechanized, on which the distribution of men, materials and machines is under the control of one department head. Under less favorable conditions, as for example, where there is a shortage of machines, the results obtained may be less satisfying; but in this case the need for scheduling the work and the machines, in order to secure full utilization of the equipment available, is more obvious.

1. *Preliminary Studies*—The work for a season is grouped and after a study of the entire picture a schedule is prepared in which the daily output for each working day is based on records of actual performance in previous years. Allowances for loss of time due to weather or transfer of equipment must be made. After this has been done, it will be possible to determine how many units or machines are required, how large a gang should be organized, what hours must be worked, and, last but of most importance, whether enough equipment is available for this work to handle it as outlined. This will afford an ample study of the proper number of men required in each gang to obtain the maximum efficiency from the units, by working them to capacity.

2. *Inspections and Recommendations*—Before the work is authorized, enough inspection work should be done to permit a comprehensive program to be drawn in such a way as to avoid irregular moves, as a means of minimizing delays. This will prove effective in holding the men on the job and also in increasing the availability of machines. A thorough inspection will frequently disclose that with some work on a specified territory this year and a possibility of further work adjoining that territory the following year, the whole project can best be handled by one program all at the same time. The savings effected will frequently compensate for any disadvantage due to the earlier or later completion of the work than originally contemplated. These facts are very familiar to those who make effective use of their programs.

3. *Character of Equipment*—If the equipment is small and readily portable, it can be assigned to a given supervisor long enough to take care of his requirements along that line and then passed on to the next supervisor who has some similar work to do and wants a machine for it. The scheduling of such work enables both men to know just when to expect it, together with the other materials, supplies, or necessary additional labor that may accompany such a machine. This is closely allied to the next item of geographic location.

4. *Location*—It is often advantageous to schedule certain work so that it is started first in areas where spring comes early and move to colder latitudes as the season advances. Some north and south roads can schedule work in the south in winter and in the north in summer, thus providing better working conditions for the men and equipment and getting the work done at the best possible time. These factors also aid in stabilizing employment and cutting down the number of men that have to be carefully trained to handle the equipment to get the best results from its use.

5. *Gang Organization*—The scheduling of the work of a gang using equipment always requires much more detailed preparation than one without the equipment, but when everything is started the progress of the work appears to be practically uniform as it is usually built up around the machinery of the gang. This makes the performance of the machinery an important cog in the wheel of progress.

6. *Field Maintenance and Use of Equipment*—In every gang where equipment is involved, there must be a man who is able to take care of the mechanical repairs. Where enough equipment is used to justify it, there should be an equipment maintainer on the job. If the number of machines is small and they are widely scattered, the operator of each unit should be able to make field repairs. Each operator or repairman should have an understudy who is learning to handle the work and who can take it over in case the operator is incapacitated, promoted, or is away from the job for any other reason.

Where several machines work together as a unit, the output of the gang must be protected by having on hand such spare parts as engines, transmission units, and the like. In some cases where frequent field repairs are necessary, complete spare machines are justified in order that the progress of the gang shall not be impaired by a machine failure.

7. *Handling of Materials and Repairs*—A program or schedule serves as notice to all departments as to where materials will be required. Materials can be furnished on a spread delivery, although purchased at a quantity price basis, shipment being made direct from the factory to the different destinations in accordance with the schedule.

Repairs to machinery can be more readily handled when the schedule shows where the gang will be on any specified date. Schedules made as far as six months in advance may be met within a very few days.

Conclusions

(a) Full utilization of the machines available can be secured only by the adhering to a schedule based on studies involving inspections and recommendations covering the work to be done. Geographical location and urgency of the work must be considered. Such a schedule can be successfully met only where the distribution of men, materials and machines is under the direct control of one department head.

(b) Such a schedule, besides more fully utilizing the available machines, will simplify their maintenance, both in field and shop, and the adherence to the schedule will provide an index to the progress of the season's work.

The report is presented as information.

Appendix D

(10) RAILWAY OWNED AUTOMOTIVE EQUIPMENT

Collaborating with Committee 13—Water Service, Fire Protection and Sanitation

F. F. Zavatkay, Chairman, Subcommittee; C. M. Angel, C. T. Blume, G. E. Boyd, Robert Faries, C. L. Fero, C. H. Morse, A. J. Neff, C. H. Ordas, E. L. Potarf, J. C. Ryan.

Introduction

The use of highway types of motor equipment by railways is constantly increasing as the value of such equipment under certain conditions is becoming better realized. The use of privately owned equipment in railway service has been a factor in demonstrating the value of such equipment and closely parallels railway experience with track motor cars some 25 years ago.

Some railways are using commercial type trucks and equipment extensively in locations subject to congestion and dense train movement, particularly where highways are convenient to the railroad. Highway vehicles are used very largely in the maintenance of way department for handling men, material, welders, tools, compressors and similar equipment. Other railways, where traffic conditions are more favorable for rail operation or where highways are not readily accessible, are using heavy type railway motor cars for large maintenance gangs and light motor cars for district maintainers. Undoubtedly, the railroads will make more extended use of highway vehicles as additional highways become available.

The following report covers the experience of an eastern railway having a total of 142 highway vehicles in service, 128 of which are used exclusively in the maintenance of way department:

Use in Maintenance Work

The reorganization of track maintenance forces, and bridge and building, and signal maintenance gangs, as a source of substantial savings, has been made possible with the

Fig. 1.—Fifteen Hundred Pound Capacity Panel Delivery, Assigned for use by Signal Maintenance Gangs or Maintenance of Way Department.

introduction of highway motor vehicles as a means of transportation for men and material to and from headquarters on pre-arranged schedules or programs of maintenance work. These savings have resulted from the consolidation of supervisory forces and the elimination of much unproductive time and work train expense.

This reorganization and motorizing of maintenance gangs is the outgrowth of experience gained in maintenance practices on a territory where frequent train movements made it necessary for track maintenance to be handled by special gangs, the results being

FIG. 2.—Two Views of 2 Cu. Yd. Capacity Mechanical Dump, Assigned for Use of Roadway and Bridge and Building Gangs of Maintenance of Way Department.

so satisfactory that the change in forces was extended to the entire system. This was done after a study of the network of state and county highways throughout the territory showed that ready accessibility to the railroad was possible in practically all desirable locations.

Careful consideration was given to the size, weight, capacity and body types in selecting the trucks best suited for the various gangs and the work to be performed by them. The following is a catalog of the trucks purchased for assignment to gangs:

CATALOG OF TRUCKS PURCHASED FOR ASSIGNMENT

Type of Truck	*Roadway*	*Bridge & Building*	*Signal*	*Total*
2-cu. yd. capacity, 7-ft. dump body	3	1	--	4
3-ton capacity, 12-ft. stake body	11	1	--	12
3-ton capacity, 15-ft. stake body	22	--	--	22
3-ton capacity, 12-ft. canopy	7	14	4	25
3-ton capacity, 14-ft. canopy	2	4	1	7
3-ton capacity, 15-ft. canopy	12	--	1	13
¾-ton capacity, 9-ft. 7-in. panel delivery	--	--	5	5
¾-ton capacity, 6-ft. 2-in. pick-up	--	--	5	5
2-ton capacity, 12-ft. stake canopy	--	--	1	1
3-ton capacity, 12-ft. combination pump	2	--	--	2
Total in department	59	20	17	
Grand total				96

Servicing and Maintaining of Automobiles

The responsibility for the servicing and maintenance of the automobiles was placed with the supervisor of work equipment who, with the co-operation of the division engineers and the purchasing department, arranged for the delivery of gasoline and oil, and the

FIG. 3.—Fifteen Hundred Pound Capacity Pick-Up, Assigned for Use by Inspectors of Mechanical Department, Work Equipment and Signal Maintenance Forces of Maintenance of Way Department.

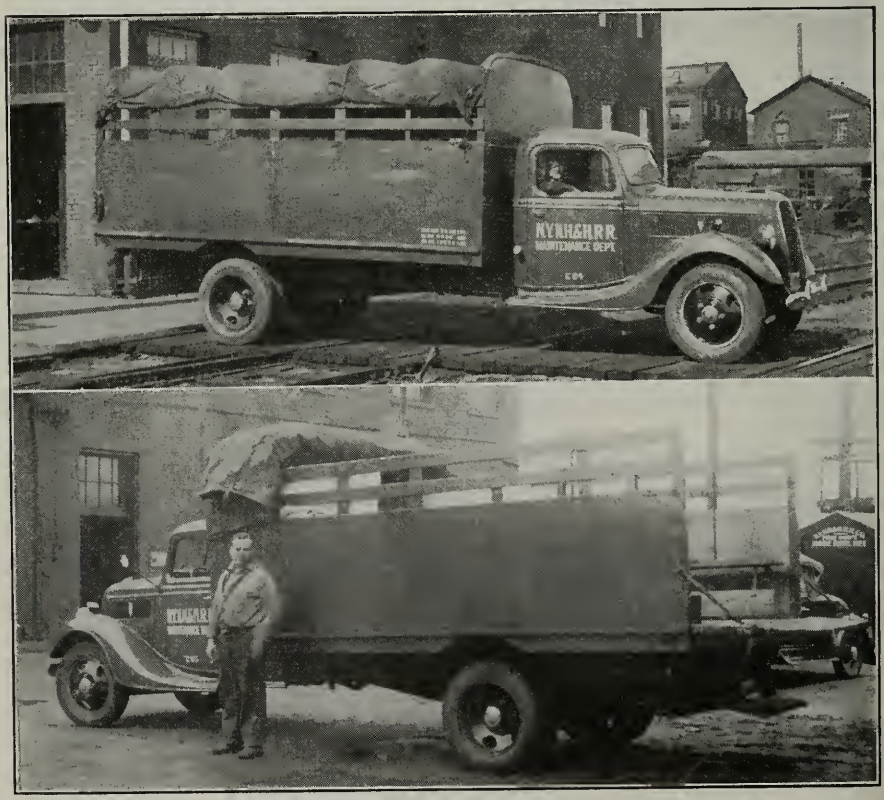


FIG. 4.—Two Views of 3-Ton Capacity Canopy, Assigned for Use by Roadway, Signal Maintenance and Bridge and Building Forces of Maintenance of Way Department.

garaging at truck headquarters, and also set up a schedule of inspections of trucks by work equipment mechanics on a mileage basis, as well as for minor and major repairs as they become necessary.

Additional Automotive Equipment

In addition to the foregoing fleet of trucks in the maintenance of way department the automobiles in the following catalog are also under the supervision of the supervisor of work equipment. Each of these miscellaneous cars fills a very important assignment and effects savings by the elimination of unproductive time and the expense for mileage in privately owned automobiles or their rental.

Catalog of Additional Cars

Type of Automobile	*Maint. of Way*	*Mechanical*	*Legal*	*Police*	*Operating*	*Total*
2-passenger coupe	9	--	--	--	--	9
5-passenger sedan	5	--	1	1	--	7
¾-ton capacity, 6-ft. 2-in. pick-up	4	6	--	--	--	10
Station wagon	4	--	--	--	--	4
40-passenger bus coaches	9	--	--	--	--	9
1½-ton capacity express	--	1	--	--	--	1
2-ton capacity, 9-ft. canopy	--	1	--	--	--	1
2-cu. yd. capacity, 7-ft. dump body	--	--	--	--	1	1
1½-ton capacity, tool body	1	--	--	--	--	1
3-ton capacity, roll-off body	--	--	--	--	1	1
5½-ton capacity, roll-off body	--	--	--	--	1	1
2-ton capacity, canopy express	--	1	--	--	--	1
Total in Department	32	9	1	1	3	46

Data on Operation

For the one-year period ending December 31, 1937, records show the following average data for the entire fleet of trucks:

Number of Trucks	*Mileage*	*Miles per Gal. of Gas*	*Miles per Qt. of Oil*	*Total Maintenance*	*Total Maint. Cost per Mile*
117	1,507,502	9.10	125.69	$16,313.24	$0.0108

Average miles per day—all units (313-day year) 41
Average miles per year—all units 12,884

Operating Cost Per Mile

165,879 gal. gasoline	$19,905
11,994 quarts oil	1,439
Total maintenance cost	16,313
Total operating cost	$37,657

From the above figures it will be determined that the operating expenses are divided approximately as follows:

Maintenance cost	43.32 percent
Gasoline cost	52.86 percent
Oil cost	3.82 percent
Average operating cost per mile—all trucks	$0.0249

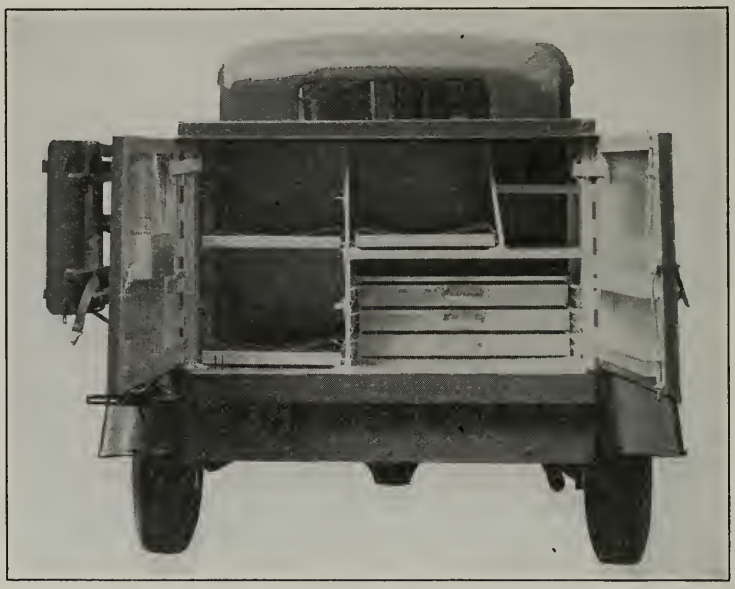


Fig. 5.—Standard Kiley Installation Body. Proposed for Assignment to Gas Engine Mechanics of Work Equipment Department.

Insurance and Safety

All automobiles are adequately protected with property damage and liability insurance as well as fire insurance and are equipped with such safety appliances as are required to comply with the motor vehicle laws of the various states in which they operate. Experience over a period of three years, embracing a total of more than three million miles of operation, has proved that personal injury and highway accidents involving these highway vehicles and the employees using them are negligible. However, it was found necessary to equip all trucks in the maintenance of way department with exhaust-pipe extensions to eliminate the hazard, to men riding in the trucks, resulting from carbon monoxide gas.

Figures 1 to 5 illustrate the trucks in use.

All of the trucks of 3-ton capacity are equipped with 32 by 6, 8-ply, heavy-duty tires and rear dual wheels. The 2-yd. dump trucks are equipped with 32 by 6, 10-ply, heavy-duty tires and rear dual wheels. Tires removed from cars are examined and when found in suitable condition are retreaded and disbursed by the stores department upon requisition for replacement tires.

Report Forms

Copies of the various forms used for reporting mileage and performance, inspections, attention given to and attention needed on the various cars, are reproduced as information and for reference. These forms are self explanatory.

Specifications

Exhibit A is a specification for 14-ft. stake bodies for maintenance of way trucks. The 12-ft. and 15-ft. stake-body trucks are similar except as to length of body. This type of body is illustrated in Fig. 4.

REPORT OF GAS ENGINE EQUIPMENT RECOMMENDED FOR SHOP REPAIRS

DIV. ..... LOCATION ..... EQUIP. NO. ..... KIND .....

CONDITION

Wheels ..... Axles .....

Frame & Attatchments ..

Transmission

Drive Members

Brakes .....

Wood Work. .....

Canopy Top & Wind Shield .....

Engine .....

Compressor .....

Radiator .....

Carburetor & Magneto .....

NEW PARTS NEEDED IN CONNECTION WITH REPAIRS

PART NO. DESCRIPTION

Inspected by .....

This report to be filled out properly in triplicate and sent to Supervisor of W. & Equipment, New Haven, Conn.

THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD COMPANY

HIGHWAY MOTOR VEHICLE INSPECTION REPORT

*Check type of inspection made. ..2,000 Mile..... 8,000 Mile.....24,000 Mile

R.R. No.....Location..... .....Date.....

Check water in radiator.....

Check wind shield wiper and blade...

Check oil level, also pressure.....

Check for oil, water, gas and grease leaks.

Operate engine for knocks or pings.....Check governor seats.....

Check choke.....Check chassis for any loose bolts and spring clips.....

Check hand brakes.....Check service brakes.....

Check water in battery and clean off corrosion.....

Check all lights including directional signals.....

Check tire inflation.....

Check front tire wear to be positive that wheels have proper caliber.....

Complete grease and lubricate at all points.....

Change crank case oil.....Check valve clearances .....

Check water pump packing, grease and repack if necessary.....

Check breaker points.....Check spark plugs and adjust points.....

Check hose connections and cylinder head nuts.....

Check gasoline strainer and fuel pump strainer.....
Check for leaks after cleaning.....

Wash air filter in kerosene and mineral oil.....
Check for leaks after cleaning.....

Check clutch pedal to have 1-1/2" clearance at toe board.....

Check fan belt.....

8,000-mile inspection

Repeat the above practice and also-
Check oil filter cartridge.....

Inspect drive shaft bearings, bracket and all points for wear.....

Remove front wheels, clean bearings, repack with grease, replace and adjust. Do the same with rear wheels if vehicle has full floating axle.....

Drain and flush radiator.....

Give chassis and body general inspection and tightening up.....

Total mileage..... Inspected by.....

(Use reverse side for explanation)

DAILY REPORT—AUTOMOBILE TRUCK

_____ Division _____ Dept. _____ Date

Truck No. _____ Reg. No. _____ Driver _____ Speedometer reading start of day _____

Headquarters _____ Speedometer reading finish of day _____

Time Reported _____ Time Relieved _____ Gallons of gasoline put in _____ Qts. oil put in _____

Repairs _____

FROM		TO		Approx. Miles	CARRIED		NATURE OF WORK (Show if AFE or C. & D.)
Place	Time	Place	Time		No. Men	Tons, Material	

Form 1214-A

THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD COMPANY

Motor Vehicles Miles—Week ending _____ 193 ... Division _____

Dept.	Car No.	Headquarters	SPEEDOMETER		Miles	Date Last Oil Change	*Remarks
			Beginning	Ending			

* Report in this column, 2000; 8000; 24000 mile inspection is completed.

THE N. Y. N. H. & H. R. R. CO.

N E T CO.
COUNTY TRANS. CO.
THE N. E. S. S. CO.

SPFD. ST. RY CO.
BERK., M. C LINES
BERK. ST RY. CO.
THE CONN. CO.
VLC. COACH LINE

E Nº 128163

.....
(NAME OF DELIVERING COMPANY)

Place..... Date.....

Has Delivered, The Above Date. Order No.....

.....Gal. Gasoline

.....Quarts Oil

.....Misc. (Give Detail)

.....

.....
TITLE

For Use, Vehicle No.....Dept.....

WHITE ORIGINAL TO BE GIVEN TO DELIVERY COMPANY WHO WILL ATTACH SAME TO THEIR INVOICE TO BE RENDERED PERIODICALLY.
YELLOW DUPLICATE TO BE RETAINED AND FORWARDED TO STRKPR.
PINK TRIPLICATE TO BE RETAINED IN THIS BOOK. ☆

Conclusions

1. Highway trucks, automobiles and other similar equipment are particularly adapted to congested territory where there are rather dense train movements and conveniently located highways. Under these conditions such equipment has proved flexible and economical for railway maintenance work. This is also true in sparsely settled territory where highways are convenient to the railroad and particularly on lines having a limited train service.

2. The sizes of trucks suitable for railway use vary from ½-ton to 3-ton capacity.

3. Large trucks with removable seating and body-top arrangement are used to permit the handling of the personnel of large maintenance gangs as well as their equipment and material.

4. Small trucks with pick-up bodies are suitable for signal, water service and telegraph maintainers and for other small maintenance gangs.

5. The stores and mechanical departments use trucks of a variety of sizes to advantage, depending on the type of service required. The type of body also varies, depending on the material handled.

6. The fact that highway vehicles have proved their value in railway maintenance has done much toward removing the prejudice against their use in railway service.

The report is submitted as information.

Exhibit A

SPECIFICATIONS FOR 14-FT. TRUCK BODIES

(If 12 ft. bodies, same specifications will govern except length)

The New York, New Haven & Hartford Railroad
Maintenance of Way Department

January 28, 1937.

General

Length overall 14 ft.

Maximum width 7 ft. 6 in.

Height, floor to underside of bows at center, 5 ft. 7 in.

Floor

One and one-eighth inch minimum thickness dressed oak, hickory or hard maple, free from knots, tongued and grooved or with metal splines, watertight.

Three 1⅛-in. by 3-in. metal strips, 15 in. center to center, to run full length of floor to be secured with countersunk flat-head bolts or rivets.

Rear 6 in. of floor to be protected by heavy metal plate flanged over rear sill.

No wheel housings inside body.

Pillars

Oak or steel section and to be firmly fastened to frame to support sides with top bows removed.

Bow pockets to be provided on all pillars except for two front bows which may be permanently fixed. Front pillars to be reinforced with steel angle securely fastened to floor frame. These pillars to support 1⅛-in. thick hardwood front section of body, extending from floor to underside of front window and to have sufficient strength to withstand shock of loading of material or shifting loads.

Rear pillars to be of sufficient strength to support loaded tailboard. Corner pillars to be mortised into floor framing.

Sides and Front

Sides to be of wood sheathing or tempered pressed wood from floor to 3 ft. above floor. Front of same material to top and to conform with shape of front bow. Window to be provided in front to match window in rear of cab.

Reinforcement of front against loading of material or shifting loads to be as in paragraph above. Entire front and side sheathing to be covered with 22-gage rust-proof steel stock, leveled and squared. To be applied without wrinkles or bulges. To remain rigid in operation without oscillation and to have lock-type seams. Provide two ⅝-in. by 4-in. slats lengthwise on sides above sheathing, full length. Window to be protected on inside by flat steel bars.

Rear of Body

Tailboard of 1¼-in. hardwood. Hinge layout to be of sufficient strength to support 1,000 lb. and with minimum gap between tailboard and floor when in horizontal position. Tailboard to be iron bound and to be complete with chain, chain loops or eyes.

Rear Step

Step to be either hinged to tailboard or suspended from truck or body frame. Step in horizontal position to have positive stop to hold in position and to have a catch to hold in vertical or closed position.

Tire Carrier

Suitable tire carrier of steel to be installed under rear of body in accessible location with suitable locking device.

Sills

Cross and longitudinal sills to be either steel section or oak and to sustain rated load of 3 ton.

Cross sills to be spaced to insure against floor deflection.

Seats

Folding seats on each side of body running full length of body. To lift up and with folding legs. Catches to be installed to hold seats when folded up.

Bows and Top Covering

Roof bows to be of 1-in. by 2-in. ash.

Top of 8-oz. waterproofed green duck tarpaulin with rope or leather straps and fastenings.

Rub Rail

To be of shaped steel over oak filler not more than 1½ in. outside panel line.

Lights, Rayflectors and Directional Signals

To conform with local and state regulations in States of operation. New York, Connecticut, Rhode Island, Massachusetts.

Painting

Remove all mill oil and dirt from steel work. Prime all steel work with metal primer. Finish with two color coats well sanded between coats.

Woodwork to receive one coat primer and two coats color.

Outside color to be Hunter Green. Inside color to be grey.

Lettering to be stenciled in white as directed.

Stencils to be furnished by Railroad Company.

Appendix E

(11) RAIL SAWS

E. H. Mills, Chairman, Subcommittee; W. O. Cudworth, J. F. Donovan, J. G. Hartley, L. B. Holt, E. H. Ness, T. M. Pittman, E. L. Potarf.

Making a satisfactory rail cut in the field has been a track man's problem since the first steel rails were laid. It has been done and continues to be done in many ways, all more or less unsatisfactory. The desire for a portable machine with which to make smooth accurate cuts in heavy steel rapidly at low cost and without danger to workmen or damage to the rail has found its answer in the development of power rail saws.

Cutting by track chisel and maul is uncertain and dangerous, even when carried out by the most careful and experienced men. When necessary to cut short pieces this method is especially unsatisfactory. The oxy-acetylene cutting torch is used to some extent and fulfills all the requirements except that it demands a skilled operator and, in the opinion of many engineers, leaves a rail end which should not be used under high speed traffic. The increased weight and hardness of modern rails makes cutting with a hand hack saw a long, expensive and laborious job.

Few Designs Available

The stationary power hack saw is a simple mechanism which has been in general use in machine shops for many years. With this as a basis and with an individual motor for power, the rail saw has been developed to make a simple matter of what was once a disagreeable task. At present there are not many designs from which to choose, as compared with most of the other power tools, due to the fact that the market is limited, but those which are built are satisfactory and fulfill every requirement with the exception of speed of cutting.

Three different manufacturers offer saws with power units and individual features of design to meet varying conditions of use. Each consists, primarily, of a renewable steel saw, held in a simple operating mechanism that is mounted on a frame which can be clamped to the rail, and driven by a power unit of about one horsepower or even less, working through a speed reducer to give a suitable saw speed. A small reservoir may be provided to feed water for cooling the blade. The conditions under which the rail saw is to be used govern the design of mechanical features which make it suitable for the work. Electric, air and gasoline motors may be used for power as conditions warrant.

Types of Power Compared

When electricity is available, the electric motor provides a most reliable source of power. Its speed is constant, there are few servicing difficulties, no excessively hot parts or exhaust gases, no starting or lubrication troubles, the weight is not excessive and the cost of current is nominal. One objection to electric power is that the work must be near a permanent current supply or else a heavy and expensive portable generator must be provided. Another and more serious objection is that an electric motor designed for the current characteristics of a certain source of current will not be usable at some other location where the current characteristics are different. These two drawbacks make the electric drive unsuitable for portable field use.

If compressed air is available, an air motor provides a light, convenient and easily managed source of power. The use of pneumatic tools and the frequent necessity of a compressed air supply for other purposes make it possible to use an air motor at many points on every railroad and the convenience and safety of this reliable power are very desirable. The motor requires very little attention other than periodic lubrication and there are no problems of fire hazards, starting, ventilation, fuel supply, etc. The objections are that it cannot be operated any great distance from the source of air supply and the cost of air is relatively high if the motor runs continuously. For every unit of power developed by an air motor, several times that amount must be provided in electrical, steam or internal combustion power at the compressor.

The small gasoline motor provides a light, efficient source of power which is almost universal in its application. It can be used in practically any location with the exception of a closely confined space having no ventilation. It is light and inexpensive to build and operate. The great advantage is that it is self contained and not dependent on an out-

side source of power. A gasoline engine has the disadvantage of requiring regular servicing of fuel, oil and repairs and is sometimes difficult to start, especially in cold weather. The danger of fire when used in buildings is always present and it is not as reliable or as safe as electricity or air. For field use this source of power is the universal choice.

Types of Machines

Two manufacturers offer machines very much alike in design, using commercial power hack-saw blades, held in a frame, driven by any of the three power sources mentioned. Both are portable as they weigh only 200 or 250 lb., depending on the type of power selected. They can be quickly set up and are designed to produce a square cut only. One cuts on the draw stroke with gravity feed under an adjustable weight and has a slow return stroke, and the saw blade is maintained constantly horizontal to the cut. The other machine starts its cut with the saw frame inclined upward, cutting on the push stroke, the blade is lifted free on the return stroke and is approximately horizontal when the cut is completed. Longer blade life is claimed where the blade is lifted from the work on the non-cutting stroke. Both are fitted with a small reservoir from which water may be fed through a suitable valve and tubing to the cutting blade to keep it cool. These machines are mechanically well designed and built, using anti-friction bearings, alloy steels and other improved features to insure trouble-free operation and long life under adverse conditions of use.

The third machine is a band-saw design and at present is available with electric drive only. It is intended primarily for shop use. The size which cuts up to eight inches in the height, suitable for rail cutting, weighs approximately 700 lb., complete with base. The plane of the wheels on which the saw runs is inclined 45 deg. from vertical. The band saw runs through roller guides on each side of the cut and these rollers spring the blade to produce a vertical cut. The frame or cutting head, as it is called, which carries the two wheels on which the saw runs and the electric motor, together with the three-speed V-belt drive, is hinged to the base and may be removed for mounting on rail skids where the use of a vice is not necessary, as when cutting rail. This cutting head alone weighs approximately 250 lb. The feed is by gravity with an adjustable weight to produce changes of pressure on the saw. The maximum section that can be cut is 8 in. high by 16 in. wide. Mitre cuts are possible. The motor automatically stops when a cut is finished. The saw runs dry with no cooling medium, and it cannot be resharpened economically.

The Saw Blades

All the saws have the capacity to cut rail 7 in. high. The rate of cut is variable, depending on the hardness of the rail, the quality of saw blade steel, the number of teeth per inch and other variables. The saws using commercial blades require from 14 to 40 min. to cut completely through a new 7-in., 127-lb. rail of ordinary hardness. Approximately half of this time is consumed in cutting through the head and web and the other half through the base. The band saw will cut through a similar rail completely in from 15 to 20 min. with a new saw.

Several grades and makes of commercial hack saw blades are available for use in the reciprocating machines, but special band saws are required for the one machine of that type. Commercial blades last from 5 to 40 cuts, depending on the many variables of hardness in saw and rail, size of rail, speed, feed, etc. Blades of the best quality of high-speed steel, with eight to ten teeth per inch, are most economical and satisfactory. On the band saw, 10 to 12 teeth per inch are recommended for the most satisfactory

combination of high cutting speed and long life. Sixty cuts in 80-lb. rail of ordinary hardness is given as the maximum life of a band-saw blade, but in practice this maximum is seldom attained.

A power driven grinder for resharpening blades of high-speed steel is available and some reduction may be made in blade cost by its use where several saws are in continuous operation. Blades may be sharpened until the "set" of the teeth disappears, usually about four times.

Some mention should be made of thin grinding wheels, inserted-tooth milling wheels and friction saws driven by power and used for cutting rail. The two latter are used for cutting at the mill. Some experimental work has been done to make use of thin abrasive wheels on machines for field use, but no such devices are generally available.

The most common use for the reciprocating saws is for fitting at terminals, yards, interlocking plants, frog and switch shops, turntables, drawbridges or any other point where numerous accurate cuts are needed. Another use is in laboratories for cutting sample sections, etc. On some roads regular programs of cropping are carried out with groups of machines in the field. On other roads this is done after the rail has been piled in storage yards on skids convenient for handling. When not used for rail work, additional uses are found for cutting pipe, bars, shafting, angles, etc., in small repair shops and in the field where smooth, unburned cuts are necessary.

Conclusions

(A) Actual savings effected by use of power rail saws are not easily obtained and like many other items of work equipment these saws are responsible for indirect economies that are known to be worth while but cannot be figured accurately.

(B) Their chief value lies in accuracy, safety, dependability and the greater amount of work accomplished.

(C) In any program of track work where time saving devices are to be considered for their economy and where quality of work, safety and speed are desired, the power rail saw should be included.

(D) It should be recognized that other faster methods of cutting are available which have restricted the use of rail saws primarily to work requiring accuracy of cut. Further development should be along the lines of greater cutting speed with the desired degree of accuracy.

The report is submitted as information.

Appendix F

(12) POWER TOOLS FOR BRIDGE MAINTENANCE

Jack Largent, Chairman, Subcommittee; C. T. Blume, G. E. Boyd, J. R. Derrick, C. L. Fero, J. S. Huntoon, N. W. Hutchison, E. C. Jackson, A. J. Neff, E. Pharand, F. F. Zavatkay.

Representatives of 16 roads have replied to a questionnaire sent out by this committee concerning the number, type and methods of assignment of portable tools and power units employed in bridge and building service. Replies ranged from those indicating heavy investment in a great variety of power units and tools—aggregating several hundred units, and indicating a high degree of specialized application—to reports of one or two recently purchased power units equipped with a small complement of tools, and to reports indicating that a study had only recently been made of the possible utility and economy to be obtained by equipping one or more gangs with power-driven devices.

The diversity of conditions obtaining on the lines reporting is perhaps indicative of the relative newness of portable power-driven equipment in bridge and building work, and, except for a few leaders, it doubtless may be estimated that it is only in the last decade that hand tools have been rapidly replaced by machines. The history of mechanization on certain lines seems to have dated from their use of tie tampers on track work, and the gradual utilization of the compressors to drive pneumatic tools on large construction or repair jobs.

Pneumatic Tools First Used

Because of its broad field of utility, and more particularly, perhaps, because of ruggedness, simplicity, and resistance to rough handling and overloading to the point of stalling, and to the effects of moisture, pneumatic equipment seems to remain most generally popular. Reports indicate that in many instances it is desirable to carry on such work as rock drilling, concrete breaking, riveting, sandblasting, spray painting, etc., in conjunction with use of rotary tools used in drilling, reaming, wood boring, nut running, etc.; and that not infrequently large volumes of air are employed in making shotcrete and pressure grouting repairs to concrete structures, or in placing concrete in tunnel linings. Occasionally it is necessary to operate tools wholly or partially submerged in water. One major line in the West has just completed the renovation of a mile-long tunnel, on which a battery of six self-propelled compressors were used as a source of tractive power to haul double-platform work cars, as well as in supplying air for drilling, chipping, shotcreting and grouting.

Among the first tools to find general application in work on timber trestles were woodborers. The use of aluminum alloys has cut the weight of these tools to a minimum. Reports indicate fairly rapid adoption of a rather recent innovation in pneumatic nut runners built on the impact principle, in three sizes made for work on both timber and steel structures. Weighing but 26 lb., this tool spins reasonably free-thread nuts at about 700 r.p.m., and tightens or loosens them quickly by rapid impacts. These tools are remarkably safe and easy on operators because of freedom from both torque and vibration, which has induced one western line to use them extensively in driving and removing long lagscrews used to secure lagging for tunnel lining forms. Piston-type nut runners are also used, as well as multivane-powered tools of widely varying sizes. When equipped with a long chuck adapter, these wrenches are sometimes employed in lieu of a heavier but more rapid screw-spike setter where GEO or similar track construction is used across bridges.

Reports indicate that a device enjoying wide popularity on all power-equipped roads is the power saw of the link-chain type, which is used with air, electric or gasoline power drive, these saws being used extensively in cutting off piling, framing bents, removing old timbering from tunnels, etc. Circular pneumatic saws, which cut to a maximum depth of 4⅛ in., and various electric and flexible-shaft types have found general application.

Both Large and Small Machines

The sizes of power units reported indicate a developed or potential demand on most roads for both large and small machines. Specialized system floating gangs are usually provided with one or several large compressors and with portable lighting equipment, while there appears to be a recently accelerated demand for ultra-portable units for use by small division gangs in making routine repairs on both wood and steel structures. One road reports that it has supplemented a battery of large air compressors with several electric generating units, driven by the large engines in heavy-duty motor cars, while

another reports the use of numerous small and relatively inexpensive self-contained generators in operating timber tools. The trend toward increased portability has been registered in some instances by the utilization of small compressors, and there doubtless is a field for further development of this versatile type of machine. Two lines report occasional use of air from steam air pumps on pile drivers in operating woodborers and other tools.

The reports would seem to indicate the increasing popularity of spray painting, large gangs apparently using air from lines supplying other tools, while considerable numbers of small, self-contained units are reported as being used by small crews. A quite general adoption of mechanical vibration, on even the smaller foundations and structures, is reflected in the number of concrete vibrators reported, these being of air, electric, and mechanical types. Relatively few tools of the flexible-shaft type were reported, this being due, perhaps, to the comparative newness of this type of drive, and to some difficulty in driving large or fluctuating-load tools by this method. The principal appeal of this method of power transmission appears to lie in extreme portability, flexibility, and adaptability to various uses, all with comparatively small investment.

Conclusion

The concensus of reports indicates that further mechanization of all bridge and building work offers worth while opportunities for increased economies.

It is recommended that this report be received as information.

REPORT OF COMMITTEE 22—ECONOMICS OF RAILWAY LABOR

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Lem Adams,
L. L. Adams,
C. W. Baldridge,
F. J. Bishop,
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W. H. Vance,
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C. R. Wright,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix H). Complete, with recommended conclusions for publication in the Manual.

2. Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work. Progress in study—no report.

3. Economics of methods of weed killing (Appendix A). Complete and presented as information.

4. Organization of forces and methods of performing maintenance of way work (Appendix B). Complete and presented as information.

5. The effect of increased weight of rail on track labor (Appendix C). Complete, with recommended conclusions for publication in the Manual.

6. Economies in labor to be effected through increased capital expenditures (Appendix D). Complete and presented as information.

7. Sanitary provisions in camps and cars for housing labor, collaborating with Committee 13—Water Service, Fire Protection and Sanitation (Appendix E). Complete with recommended conclusions for publication in the Manual.

8. The relative economy of combined vs. separate bridge and building gangs. Progress in study—no report.

9. The effect of modern equipment and machines on bridge gang organizations and efficiency. Progress in study—no report.

10. The economic relation between supervision and labor (Appendix F). Complete and presented as information.

11. The effect of sudden fluctuations in maintenance expenditure allowances on maintenance costs (Appendix G). Complete, with recommended conclusion for publication in the Manual.

The Committee on Economics of Railway Labor,
F. S. Schwinn, *Chairman.*

Bulletin 407, December, 1938.

Appendix A

(3) ECONOMICS OF METHODS OF WEED KILLING

C. W. Baldridge, Chairman, Subcommittee; J. I. Catherman, W. S. Hanley, A. C. Harvey, H. T. Livingston, J. B. Martin, F. H. Rothe, H. M. Stout, W. H. Vance.

This subject has been under study by the committee for some years and in 1935 it was decided that it properly should be divided into two parts, the first part to include weeds and vegetation growing in the roadbed and the shoulders thereof, the second part to include weeds and vegetation growing in the right-of-way outside of the roadbed, and in other grounds for which the railway company is responsible.

In the convention held in March 1936 (Proceedings, Vol. 37, p. 236) the committee presented an extensive report covering the eradication of vegetation in the roadbed. This year it is presenting a study of the eradication or control of vegetation on the right of way and lands other than the roadbed. Previous reports have shown that it is desirable to eradicate completely all vegetation growing in, or upon, the roadbed and shoulders thereof. Such is not the case, however, on grounds outside of the shoulders of the roadbed for the reason that a well sodded surface protects the right-of-way from erosion by water or wind, and keeps down dust. High weeds, or in fact high vegetation of any kind, are undesirable because they obstruct the view, particularly near road crossings where it is important that users of the highway have a clear view of the tracks for as great a distance as possible. High weeds near the tracks interfere with movements on the right-of-way, and also prevent enginemen from seeing signs along the way or obstructions ahead, especially at curves. High weeds and high grass when they have been winter-killed or become dry, present fire hazards which are objectionable, and at all times such vegetation presents an unsightly appearance.

In reply to the request of the committee, more than 30 railways have furnished information regarding their practices and methods used in controlling the growth of high weeds and vegetation on their right-of-way. The maintenance department of one prominent railway located in a part of the country where weed growth is heavy, has supplied a description of its practices, giving a typical example of the problem and its economic handling. The practices are described as follows:

> Our main line right-of-way varies from 100 to 200 ft. in width from right-of-way line to right-of-way line, with an average width of about 130 ft. It is our practice to cut the weeds and grasses for the full width of right-of-way during the late summer and early fall months. After the cut grasses and weeds have dried they are burned where they fall, during the months of October and November when weather conditions are suitable.
>
> Where farmers cultivating adjacent lands so desire, they are permitted to plant the right-of-way up to the outer edge of the roadbed ditches or toe of slopes, under an agreement which provides that no high growing crops, such as corn, will be planted in vicinity of road crossings.
>
> The high growing vegetation consists of broom sedge, ragweed, goldenrod, Spanish needles, sheepburr, dog fennel, partridge berry, black berry, bramble briar, coffee berry, iron weed, various kinds of cane grasses, Johnson grass, other grasses, etc. Natal boy, while not a native plant, has spread rapidly in many localities. In the swampy and low lying lands will be found bay bushes, willow, Laurel, maple shoots, witchhazel, etc., in addition to the cane grasses and other weeds. Throughout the territory served by the Coast Line vegetation growth is prolific. Such

grasses as may be suitable for hay are so mixed with weeds that there is little or no inducement for adjacent farmers to harvest the same.

Up to about twelve years ago all annual right-of-way cutting was done with hand tools, scythes, briarsnaiths, and briar blades. Then began a program of gradually leveling up the right-of-way by spreading back the spoil from roadbed ditches, filling minor holes, leveling the surfaces and side slopes of borrow pits, removing stumps (yellow pine stumps turn to "lightwood" and last indefinitely), grubbing up willow, bay bushes, etc., so as to improve the appearance of the right-of-way and to permit the operation of mowing machines for the annual clean up. No extra labor has been employed for the purpose. At first a few horses and mules were purchased and worked in pairs for leveling the right-of-way with drag pans. In general, one driver was all the labor assigned and rarely has more than one team been operated on a roadmaster's district at the same time. Stumps are being gradually removed by the section forces, by piling and burning old ties over them when retimbering, by grubbing, and by some use of stump pullers. Subsequently light wheel-type tractors have been used for handling drag pans in addition to the use of mules. Three light crawler tractors equipped with bulldozers are doing very satisfactory work. In all about twelve mule teams and twice that number of tractors are now so employed.

Considerable progress has been made, and it is now practicable to mow long stretches of the right-of-way by machine; on some sections from two-thirds to three-fourths of the section can be so mowed. The swampy lands are cut by hand. The mules and tractors are used to draw the mowing machines, which are of the heavy farm type. The extra heavy cutter bars and teeth recently developed for mowing of highway and railroad shoulders and side slopes have provided a material improvement to the mowing machines. The vegetation is allowed to dry where it is cut, and at a suitable time is burned by the section forces. Mowing the right-of-way is proving very satisfactory.

The farm type of mowing machines, drawn by section motor cars equipped with reduction gears for slow speed operation, are also used for mowing roadbed shoulders. This spring we purchased one railroad-type mowing machine, equipped to cut both shoulders simultaneously, for cutting shoulders and a short swath on side slopes of embankments.

It has not been considered practicable to treat the right-of-way with chemicals, of either the non-poisonous or poisonous types, for weed killing. The non-poisonous types have been used to a limited extent for the treatment of track in yards and on line of road. There is also the fire hazard to be considered in application of the more economical non-poisonous types of chemical weed killer. Except where exceptionally heavily applied, the non-poisonous varieties of chemical weed killer require annual application to be effective in retarding future growth. The arsenical weed killer will render soil sterile after several applications. It is highly desirable to retain the low growing grasses on the right-of-way for the prevention of erosion of the soil and to keep down dust during the summer and early fall months.

This right-of-way improvement work is being accomplished by the section, and various other forces, as circumstances and other duties permit. Therefore it is not readily practicable to set up a cost-accounting system by units to cover such work, and this has not been done. Again conditions vary so from place to place on the same railroad, and as between railroads, that the unit cost of right-of-way improvement, per acre for instance, would be of but little value for comparison purposes. Neither have we as yet attempted to set up unit costs of right-of-way mowing.

A report from another railway, of smaller mileage and located in an excellent farming district, shows the economies resulting from the leasing of available parts of the rights-of-way for the producing of crops. The report reads as follows:

> The effect of farming such portions of right-of-way as are suitable on a 100-mile section of line in Illinois is shown below. The width of right-of-way varies, but is as much as 200 ft. in various miles. The object is to have a good looking clean right-of-way at all times and also to reduce to a minimum the cost of keeping it that way.

Total acres of right of way involved	2,762
Less acres occupied by tracks, etc.	319
Total acres either farmed or to be kept clean	2.443
Less acres farmed	1,397
Total acres to be kept mowed	1,046
Gross cost of mowing in 1937	$7,459
Average cost per acre	7.13
Direct returns from farming operations (rents, sale of crops)	3.945
Net cost of mowing right of way	$3,514
Average cost per acre	3.36

> Without any agricultural operations on the right-of-way the total of 2,443 acres would have required mowing.

2,443 acres at $7.13 =	$17,418
Actual net cost for reduced acreage, was	3,514
Total returns from agricultural operations (savings)	$13,904

A canvass of railways for information brought numerous replies covering many of the features given in the letters quoted above, but in no case, was there any advocacy of killing all vegetation on the right-of-way. The methods used for controlling high growing weeds, etc., may be summarized as an almost uniform response of "by mowing and chopping." A well sodded surface of the right-of-way protects against erosion by water or by wind, and thus avoids many bad ditches which would require backfilling, expensive riprap or other protective measures.

In some localities, where railway rights-of-way are leased to farmers or gardeners for use in growing crops, the erosion damages resulting from the exposure of the surface will offset if not exceed the returns received from such use of the ground. In such localities, therefore, the subject resolves itself into a study of means and methods for keeping the grounds covered with some form of protective vegetation and at the same time keeping the vegetation low enough to avoid obstructing of views and movements, and in a neat and sightly condition.

In the matter of economies to be effected, the only methods which seem to be of merit are—

(1) The practice of more foresight when tracks are being constructed or improvement work is being done, to the end that the surface of the right-of-way be left smooth enough to permit of its being mowed by machines.

(2) That, wherever it is practical to do so, stumps and rocks be removed and that uneven places and steep banks be smoothed out by use of tractors equipped with bulldozers or by any method which is economical.

It is not necessary that the surface of the ground be made level; in fact, in most cases it is better that it be made an inclined surface sloping away from the track. In

many cases the smoothing of the ground surface to permit of machine mowing can be combined with improvement of drainage conditions. By making a ditch along the outside edge of the right-of-way and using the excavated material to fill in the old ditches, borrow pits, etc., and finishing the job by making a slope from the top of the old berm to the bottom of the ditch, the double purpose of keeping flowing or standing water at the farthest possible point from the roadbed and at the same time providing a surface suitable for machine mowing, is accomplished.

After smoothing up the surface of the right-of-way, it should be seeded to the variety of grass which is best adapted to the purpose in the locality, and mowing by machine can then keep undesirable vegetation cut so short that but few kinds, except grass, can survive. In some localities some form of meadow grass may be seeded and the hay which it will produce can be made to pay for the cost of mowing. Care must be taken in such attempts that the mowing for hay does not denude the ground to such an extent that insufficient protection against erosion remains.

Conclusions

(1) It is generally found to be an economy to provide a smooth right-of-way to the extent that will permit of mowing with machines.

(2) It is generally a further economy to seed the right-of-way after smoothing it, with grass suitable for the locality.

It is recommended that this report be received as information.

Appendix B

(4) ORGANIZATION OF FORCES AND METHODS OF PERFORMING MAINTENANCE OF WAY WORK

H. E. Kirby, Chairman, Subcommittee; F. J. Bishop, W. H. Brameld, W. C. Brown, R. R. Cummins, H. H. Harsh, H. T. Livingston, A. E. Perlman, P. T. Robinson, C. R. Wright.

CONSTRUCTION AND MAINTENANCE OF WOODEN TRESTLES

In previous years the studies presented by this subcommittee have dealt with the major operations required in the maintenance of railway track and roadway. These operations, comprising a definite number of steps, by their nature were susceptible of complete analysis. Once the required number of such steps was determined, they were repeated in identical manner during a time interval necessary to produce a given result. It was then possible to evaluate the several steps, and arrange for each man the work he was to perform in routine manner, repeating the same operations daily. It may be said, then, that these major jobs were of a type to lend themselves more or less readily to definite organization of the working forces.

The present assignment, covering forces working on wooden trestles, can not be given precisely the same treatment as outlined in the foregoing paragraph. The nature of the work is different, as it is not a constant repetition of identical operations. Rather the process is a mixture of several operations, some of which are similar, but in which the similar steps do not follow one another with the same regularity. Hence, the problem lies more in the determination of economical gang size and consist to carry out a definite program than in a detailed analysis of gang organization and application.

Data Obtained Through Questionnaire

In an effort to determine current practice the subcommittee approached the problem by addressing a questionnaire to a number of railways. Response to the questionnaire was not as general as anticipated, but the result is considered to be representative of practices in effect on most of the railways which do this work in some volume.

These data were assembled and equated so far as practicable for several of the various conditions encountered in trestle work. It appears clear from individual reports that the volume of new construction during the past few years has been inconsiderable. Also, it was found to be the practice of some railways to contract all new work of this kind. Whatever the trend, it is customary on many railways to program sufficient pile driving and decking to keep at least one organization, with pile driver, busy during the whole or part of the year. Where this is the practice two gangs are usually used, (1) a pile-driving unit, the function of which is the driving of piles and capping of bents only, and (2) a decking gang.

The subcommittee presents what are believed to be economical gangs for (1) pile driving and decking, and (2) ordinary trestle maintenance. The suggested organizations for pile driving and decking are:

Pile-Driving Gang

1 Foreman
1 Assistant Foreman or lead man, when needed
10 Carpenters, helpers and laborers
1 Pile-driver operator
1 Pile-driver fireman

Decking Gang

1 foreman
1 Assistant foreman or lead man, when needed
12 Carpenters, helpers and laborers

Working 260 days per year, with an average productive time of 6 hours per day, the first gang should drive 187,000 lin. ft. of piles per year, while the second gang should construct 730 panels, averaging 12½ ft. in length, of new decking per year. The gangs also perform all work necessary in opening and closing trestles for work, and retire the old structures, cleaning up all old material. The gang should be equipped with a self-propelling, full-revolving crane, power sawing, boring and wrenching tools, small tools and supplies. A crane operator is to be added to foregoing organizations as conditions may require.

It was established that the general concensus of policy on the majority of railroads, during years for which a small pile-driving program is proposed, is to use a combination gang for driving and decking the structures.

It is estimated that such a gang, composed of:

1 Foreman
1 Assistant foreman or lead man, when needed
14 Carpenters, helpers and laborers
1 Pile-driver operator
1 Pile-driver foreman

will drive 90,000 lin. ft. of piles, and complete the decking of 430 panels of open-deck structures annually, under conditions similar to those outlined in the preceding paragraph, i.e., the same daily detention and annual effective time, using similar equipment.

Gangs for Ordinary Maintenance

Gangs for ordinary maintenance or repairs are selected with less certainty of economical functioning, due to the diversity and range of their work. However, an organization composed of one foreman and eight carpenters, helpers and laborers is believed to be an effective gang for general purposes. Since adherence to a program for spot maintenance work is ordinarily more difficult than is the case of larger gangs working on out-of-face

jobs, proper care should be taken in this respect. While a gang is engaged with some of its larger jobs, the assignment of a crane may be necessary to assist in handling the heavier timbers. Likewise, there will be cases in which economy will result from providing a small power unit for use in boring and wrenching.

The length of territory assigned each maintenance gang varies, of course, with the potential volume of work. As it is not always practical to establish definite limits of the territory to be covered by a maintenance gang, the practice of one southwestern railroad in defining the annual volume of work assigned each of its ten maintenance gangs is particularly noteworthy. The report from this road states, in part: "Normally we assign sufficient territory to each gang so that during the course of a year's time, or 275 working days (1½ hours daily interruption anticipated), the gang will use approximately 400,000 ft. b.m. of bridge lumber and 150,000 ft. b.m. of bridge ties . . . We have an effective total of ten such gangs assigned to the maintenance of 294,000 lin. ft. of wooden trestles scattered over 2,700 miles of operated line. The average gang will have a district of about 270 miles and take care of the ordinary maintenance of approximately 29,000 lin. ft. of trestles of both treated and untreated timber construction."

Programming Important

As with any enterprise, the importance of a carefully prepared and executed program for trestle repairs or construction can not be overemphasized. Intelligent programming should of course be based upon factual data, probably best secured from a personal inspection by a system bridge officer in company with local maintenance officers. There are several effective methods now in use. In most cases one general inspection, apart from other periodic inspections, is made annually in the early fall. Information is then assembled, and program prepared for inclusion in next year's budget. Following the approval of the program, steps are taken to insure the arrival of all materials on the dates required, and the labor allowance is set up to cover the necessary organizations.

All of the gang organizations here given are designed for maximum production with minimum waste. The character of the work, however, is such that a certain flexibility is unavoidable: jobs differ; the personal equation is always a variable; co-ordination of gang movements and material shipments is sometimes lacking; gang travel time and detention from traffic, while estimated at what is believed a reasonably average figure, varies with each job and with the local conditions of each railway. It will be necessary, for instance, to use a laborer for general utility—as watchman, flagman or waterboy. Likewise, in a routine operation such as pile-driving, the working gang will necessarily be modified somewhat to the extent to which the deck must be opened to permit driving. It might be added that efficiency—as well as safety and convenience—will result from using (on these operations proper) six men or multiples of six in capping, eight men or multiples of eight in decking, and six men or multiples of six in the repair gang. A six-pile bent permits six men to work without crowding when the bent is ready to be cut off, and six men can occupy average size scaffolds with safety and convenience.

While trestle work ordinarily requires greater concentration of men than is practicable in the larger gangs used in the major track maintenance operations previously studied and reported upon, lack of supervision is at once evident in lowered efficiency, in wasted time and materials, and in disruption of the regularity of such operations as are performed by the men in somewhat routine manner. The responsibility for this of course is in local supervision, by foreman and assistants. To see that the entire program is executed according to schedule, adequate division and system supervision is not less important.

Recommendation

It is recommended that this report be received as information.

Appendix C

(5) THE EFFECT OF INCREASED WEIGHT OF RAIL ON TRACK LABOR

Elmer T. Howson, Chairman, Subcommittee; Lem Adams, C. W. Baldridge, Armstrong Chinn, D. A. Kuebler, G. M. Magee, J. B. Martin, G. M. O'Rourke, H. M. Stout, A. A. Woods.

As the railways have gone more universally to the use of heavier rail during the last few years, it is to be expected that numerous studies will be undertaken to determine the economies resulting from this added expenditure. As a result, several reports presented to this association have referred to this trend and to the results therefrom, especially a report presented by this committee at the last convention (see Proceedings for 1938, Vol. 39, page 585). However, the report which your committee now presents is believed to be the first to be brought before the association dealing specifically and exclusively with the effect of increased weight of rail on track labor.

In studying the effect of increased weight of rail on track labor, the committee was faced with the fact that the system of accounting prescribed by the Interstate Commerce Commission does not lend itself to an allocation of costs in such a way that the items of track labor that are affected by increasing the weight of rail can be segregated wholly from those that are affected by other causes, and that this would probably be true of any other practical system of accounting. The effects of heavier rail on track labor are both direct and indirect, and this labor is also affected by numerous factors that are independent of the weight of the rail, while some effects, such as the life of ties, can be determined only after a considerable number of years. For these reasons, the effect on track labor of increasing the weight of rail cannot be stated statistically without making certain assumptions that are not universal in their application because of the widely varying conditions under which rail is employed.

The committee's study covered a total of 39 roads in the United States and Canada, having a combined line mileage of 226,000. The survey of these roads indicated that while a few of them adopted sections heavier than 100-lb. as far back as 1916 and 1917, the 85, 90 and 100-lb. sections predominated to and including 1920. From 1921 to 1929, however, there was a marked trend toward the adoption of sections heavier than 100-lb. Some of these roads went directly from 85 and 90-lb. rail to weights of 110 lb. or heavier, while others stepped up to 100 lb. and later to the heavier sections. In general, those roads that had adopted 110 and 130-lb. rail during this period changed to the 112 and 131-lb. sections in 1934 or 1935. A few roads did not begin to lay rail heavier than 100-lb. until 1930 or later, while others that were using the 110 and 112-lb. sections also began to use 131-lb. rail on curves, on heavy grades and on lines of densest traffic.

The committee found that 112-lb. rail is in service on lines having a traffic density as low as 1,430,000 gross tons per mile per year, and as high as 27,000,000 tons; the range for the 130-lb. section is from 3,000,000 tons annually to 60,000,000 tons; while 100-lb. rail is still in service on three roads having maxima of 9,600,000, 13,000,000 and 25,000,000 gross tons annually, respectively. Other heavy sections in current use weigh 127, 136 and 152-lb.

Light Rail Not Standing Up

In general, in arriving at the decision to increase the weight of rail, no consideration was given by the roads under study to the possible savings in track labor, or at most this was a secondary consideration, although every road studied expected that some savings

of this character would result. With few exceptions, the primary reason was that with increasing axle loads and higher speeds of operation, the lighter rail was not standing up, so that stiffer track became a necessity regardless of other considerations. Most of these roads foresaw that with the still heavier wheel loads and the still higher speeds, the amount of labor necessary to keep the track to the desired standard, together with all other costs for track maintenance, would increase unless they adopted heavier rail, so that heavier rail became a matter of avoiding mounting labor costs rather than that of reducing the labor item below the existing level. In other words, it was considered that by laying the heavier rail and maintaining the same force as then employed, the standard of track excellence could be raised. Several roads based their decisions on studies that showed that by increasing the weight, the life of the rail could be prolonged sufficiently to make the added investment economical on a capitalized yearly cost basis, and ignored the possible favorable results on labor costs and on costs for other items of the track structure.

High Speeds Increase Need for Heavy Rail

Obviously, in the cases which have been mentioned, the original installations of the heavier rail were confined to districts having the greatest density of traffic, and on not a few roads they were not extended beyond such districts, lighter sections still being purchased for use on primary lines of lighter traffic. Beginning with 1934, however, a new factor was introduced with the sharp increases that were made in the speeds of both passenger and freight trains, for smooth-riding track and assurance against track defects that might endanger safety at high speed have become paramount on those lines over which high-speed trains are being operated. For this reason, there has been a noticeable trend toward the extension of heavy rail sections to lines of lighter traffic. This has given the committee an opportunity to study the effect of increased weight of rail on track labor under a wide variety of conditions.

Owing to the increase in stiffness, both vertically and laterally, as the weight of the rail increases, and the consequent better distribution of the traffic loads over the ballast, other conditions being equal, there is a considerable reduction in the amount of labor required to keep the track in line and surface. The committee found, however, that the amount of this reduction varies within relatively wide limits by reason of variations in physical conditions and the volume and character of the traffic. None of the roads under study had records that showed definitely the magnitude of this reduction, although the testimony was general that it has been substantial. Estimates by responsible maintenance officers of the reduction in this labor item ranged from 20 to 50 percent. It was found that the savings in this item vary rather definitely with the volume of traffic and the speed of trains, increasing as the volume and speed of traffic increase.

While a large part of the reduction in the amount of labor required for lining and surfacing can be attributed directly to the stiffness of the rail and a better distribution of the loads on the ballast, it must be recognized that there are also indirect reasons for this reduction, as well as causes in no wise connected with the weight of the rail. The larger sections provide deeper fishing and, therefore, stronger joints; the larger tie plates that accompany the heavy rail reduce the wear on ties and tend to hold gage better, and where the tie plates are fastened independently of the rail fastenings, this wear is still further reduced and there is less widening of the gage; new ties are pre-adzed and when rail is renewed modern practice demands the use of mechanical adzers, thus providing a better and more uniform bearing for the tie plates and rail; and stronger joints reduce the churning of the ballast at the joints. All of these improvements, which are independent of the rail itself, except the joint, have a definite influence in retarding the tendency

of the track to get out of line and surface and thus contribute to the reduction in the amount of labor required to maintain line and surface. It is not possible to evaluate these items, either individually or in combination, or to estimate with any degree of accuracy the extent to which they affect the labor required for lining and surfacing.

Heavy Rail Outlasts Lighter Sections

Experience has shown that under average main-line conditions the life of heavy rail is greater than that of light rail. The extent to which this life is increased depends on the differences in the weight of the two sections; the design of the joints; whether heat treatment is applied to the rail; the alinement and grade characteristics of the road; the extent to which curve lubrication is practiced; the volume and character of the traffic; the magnitude of the axle loads and the speed of trains; the condition of the roadbed, that is, of the ballast, the subgrade and drainage; and the standard of maintenance.

One of the roads under study ignored the saving in labor for track maintenance, basing its decision to apply 130-lb. rail in place of 100-lb. rail on the annual capitalized cost of the rail. On a district having a traffic of 23,000,000 gross tons per mile of track per year, it was calculated that since the 100-lb. rail had an average life of 5½ years, the 130-lb. section would have to last 8½ years, or 55 percent longer, to equalize the cost. As a matter of record, the 130-lb. rail has now been in service for 9 years with no removals and the minimum life will be at least 10 years, with the average considerably more. This illustrates a situation that has a definite bearing on the effect of heavier rail on track labor, for where the life of the rail is increased 50 percent, compared with the light rail it displaces, the labor cost of rail renewal is reduced by one-third; if the life is doubled the labor cost for this item is cut in half; and if the life of the rail can be extended 2½ times, the labor for laying rail will be 60 percent less. Actual experience in the saving effected in this item of track labor ranged from 20 to 60 percent.

Life of Ties Increased

Increasing the weight of rail increases the life of ties by decreasing the abuse to which they are subjected in service. By reason of its greater girder strength, the larger rail distributes the traffic load over a greater number of ties, thus reducing the load on the individual ties. Although they are entirely independent of but usually incidental to heavy rail, large tie plates also contribute to decreasing the intensity of pressure on the ties by spreading the reduced load over a greater area of the surface of the ties. Ties fail in large numbers as a result of abrasion induced by relative movement between the tie plate and the tie, and this mechanical action is greatly increased by the wave motion in the rail. Since the heavy rail is stiffer, it has less wave motion and thus prolongs the life of those ties that fail from plate cutting. Independent fastenings for the tie plates still further reduce this type of mechanical destruction.

Spike cutting is another fertile source of tie failure, and because rail renewals are less frequent and less gaging is required with the heavier rail and larger tie plates, the life of ties subject to this type of failure is prolonged. Because of the many other factors that affect tie life, however, such as the species of wood, the type of treatment, the practice of pre-adzing and pre-boring, the character and condition of the ballast and others that are in no wise related to the weight of the rail, it is not possible to state in concrete terms the effect of increased weight of rail on the labor involved in tie renewals, although it is clearly apparent that the heavy rail will result in an increase in the life of ties, and thus effect a reduction in the labor required for tie renewals.

Owing to the greater girder strength of the rail itself and to the opportunities the higher fishing affords for better joint design, it is the general experience that an increase in the weight of rail tends to decrease the amount of labor required for picking up joints. There is also a reduction in the labor required for reconditioning the joints and replacing joint bars where heavy rail is used. The effect on labor of this item varies almost directly with the volume of traffic, axle loading and speed.

Heavy Rail Saves Ballast

Lack of stiffness accentuates wave motion in rail under the rolling wheel loads, thus causing increased vertical movement in the ties. Investigation has shown that the intensity of the blow delivered by the tie to the ballast bed under fast moving trains varies approximately as the square of the amplitude of the wave motion, that is, as the vertical distance the tie moves. These repeated blows tend to drive dirt up from the subgrade through the ballast and foul it. Then, with favorable conditions of moisture, churning results. While churning may, and frequently does, occur at any tie, it is more frequent and generally more aggravated around the joints.

Since the greater stiffness of the heavy rail reduces the amplitude of the wave motion and, therefore, the vertical movement of the ties, churning is reduced and the amount of labor involved in surfacing the track, over and above ordinary maintenance requirements, is eliminated or reduced. The committee obtained no information as to the magnitude of this excess labor requirement over ordinary maintenance but refers to the report on this subject by the Committee on Ballast, on page 254, Vol. 30, of the Proceedings of this association, in which it is stated that the cost of maintaining churning track (joints) is from 2½ to 4 times that for track in which there are no pumping joints.

Furthermore, after churning track has been surfaced repeatedly, it becomes necessary either to clean or discard the existing ballast, give the track a general raise, and restore the ballast section. This work calls for a large expenditure of labor. Increasing the weight of rail reduces the tendency of the track to churn and increases the intervals between general surfacings, with a consequent appreciable saving in labor.

A Measure of Economy

In its report for 1930, the Rail Committee included a monograph by A. N. Reece, chief engineer, Kansas City Southern, giving the results of a study to determine the economic weight of rail for that road. Five weights of rail were placed under study, 85-lb., the existing standard for the road; three, 100, 115 and 127-lb., that were laid for experimental purposes; and the 150-lb. R.E. section. Largely from data obtained in field tests, it was concluded that the effect on track labor of increasing the weight of rail would be as shown in Table I. As a result of this study, it was determined that 137-lb. rail would be the most economical section, but for reasons stated in the monograph, 127-lb. rail was chosen. At that time, 1927, the gross ton miles per mile of road on the districts where the 127-lb. rail was laid, ranged from 4,560,000 to 6,330,000.

Beginning in 1930, traffic decreased and reached its low point in 1932 and 1933. An analysis of the 1932 traffic indicated that while the most economical section for this road in 1927 was 137-lb., this had dropped to 125-lb. in 1932, but as the section nearest to this weight was 127-lb., this weight was continued as standard. In response to an inquiry as to the economies in track labor actually effected by reason of the increased weight of rail, the committee was advised:

"In 1935, when the volume of traffic had increased from the low point of the depression, the railway made another study of the economics of heavy rail, the traffic for this year being selected in the expectation that it would be the average for a number

of years. During 1935, the minimum gross ton miles per mile of road on districts where the 127-lb. rail was in service was 2,840,000 and the maximum 4,740,000. Table II shows the cost of track labor (all items) per mile per million gross ton miles for each weight of rail and the saving compared with the cost for the 85-lb. section. In this study the traffic density was taken as 3,130,000 gross tons per mile of road."

TABLE I

KANSAS CITY SOUTHERN

EFFECT ON TRACK LABOR OF INCREASING THE WEIGHT OF RAIL

Rail Section	*Track Rating Percent*	*Labor Per Mile Per Year Man-hours*	*Comparative Maintenance Labor Percent*	*Cost of Labor Per Mile Per Million G.T.M.*	*Saving Per Mile Per Million G.T.M.*
8521	34	3,150	100	$120	$ 0
10025	50	1,950	62	74	46
11522	62	1,470	47	56	64
12722	67	1,280	41	49	71
15025	80	950	30	36	84

TABLE II

KANSAS CITY SOUTHERN

ESTIMATED COST OF TRACK LABOR FOR VARIOUS WEIGHTS OF RAIL IN 1935, (BASED ON ACTUAL COSTS FOR 85-LB. RAIL) COMPARED WITH ESTIMATED COSTS IN 1927

Rail Section	*Cost of Labor Per Mile Per Million G.T.M.*		*Saving Per Mile Per Million G.T.M.*	
	1927 Est.	*1935 Actual*	*1927 Est.*	*1935 Actual*
8521	$120	$79	$ 0	$ 0
10025	74	49*	46	30*
11522	56	37*	64	42*
12722	49	32*	71	47*
15025	36	24*	84	55*

* Estimated from actual costs for 85-lb. rail.

The committee was advised further that "the unit measure of economy shown in the tables is labor per mile per million gross tons, which is indisputably the most uniform measure obtainable because traffic density, physical characteristics and all other factors are included. The use of heavier rail has made it possible to reduce the labor force and lengthen sections. This latter reduction in force can be accomplished during periods of light traffic and to take advantage of well-built track and high standards of maintenance to carry through periods of low revenue. By measuring economy in gross ton miles of traffic, the result is more positive. However, expressing labor in the usual terms, it was found that when a section is laid with 85-lb. rail, its length must be reduced by about five track miles or, by comparison, the same gang can maintain five more miles of 127-lb. track."

A Record of Heavy Rail

On the Bessemer & Lake Erie the committee found another clear-cut record that shows quite definitely the effect of heavier rail on track labor. In 1917, this road began to replace 100-lb. rail with a section weighing 130 lb., and by 1921 about 60 percent of the main-track mileage had been laid with the heavier rail. There was a decided reduction in man-hours beginning with 1922, with a continuing decrease as more of the heavier rail was laid. The life of the 100-lb. rail was 6 years, while that of the 130-lb. rail is 13 years, which has reduced the cost of laying rail by more than 50 percent.

Table III shows for this road the gross ton miles per mile of road per year, the man-hours for all items of track labor and for track laying and surfacing only, and the relative reduction that has been made in these items for the period from 1917 to 1931, inclusive. This statement was confined to the years prior to 1932 because the effect on track labor of the use of treated ties, which was started in 1928, was becoming apparent, while the improvement in ballast conditions, which had its beginning in the same year, was also beginning to show its effect. Again, the adoption of new maintenance methods about 1930, combined with the ties and ballast, made it impossible even approximately in subsequent years to assign to the heavier rail its share in the continued reduction in track labor. By confining it to the period prior to 1932, therefore, the record affords a reliable indication of the reduction that can be effected in track labor through increased weight of rail alone.

While the remaining roads under study did not have as definite records of the reductions that had been made in track labor by reason of the adoption of heavy rail, with the exception of one road, the maintenance officers of these roads were unanimous that substantial reductions have been realized, the estimates for all items of track maintenance ranging from 20 to 60 percent. Some of the roads conceded that where a high density of traffic prevails, the saving in labor is sufficient to justify the investment in heavy rail. For lines of lighter traffic, this justification becomes less pronounced and finally reaches a point, which must be defined in the light of each particular case, where considerations other than the saving in labor must participate to justify the increase in weight.

TABLE III

BESSEMER & LAKE ERIE

STATEMENT OF G.T.M. PER MILE OF ROAD, TRACK DEPARTMENT, STRICT MAINTENANCE MAN-HOURS, AND ACCOUNT NO. 220, STRICT MAINTENANCE MAN-HOURS, FOR THE YEARS 1917 TO 1930, INCLUSIVE

Year	*G.T.M. Per Mile of Road*	*Track Dept. Strict M.W.&S. Man-hours*	*Ratio*	*Acct. No. 220 Strict M.W.&S. Man-hours*	*Ratio*
1917	19,173,838	1,765,816	100.6	1,256,849	100.0
1918	17,805,087	1,741,743	98.6	1,261,588	100.4
1919	15,218,810	1,460,326	82.7	1,209,411	96.2
1920	15,846,963	1,394,059	78.9	1,066,525	84.9
1921	13,124,953	1,252,451	70.9	1,039,375	82.7
1922	15,284,593	930,399	52.7	711,052	56.6
1923	20,931,885	1,036,976	58.7	810,564	64.5
1924	16,405,542	1,142,754	64.7	867,368	69.0
1925	18,627,945	956,280	54.2	715,816	57.0
1926	19,306,343	941,446	53.3	705,595	56.1
1927	17,074,310	914,985	51.8	675,792	53.8
1928	18,302,893	840,254	47.6	585,430	46.6
1929	20,300,595	870,827	49.3	611,612	48.7
1930	16,507,213	796,996	45.1	589,745	46.9
1931	9,697,515	704,657	39.9	501,991	39.9

From the committee's study it appears to be certain that the installation of heavy rail in any main-line track will reduce the amount of labor required for track maintenance, but the committee was unable to collect information upon which it could base conclusions as to what sections of rail will be the most economical with respect to labor under varying traffic densities. For a discussion of this phase of the matter, the committee refers to Mr. Reece's monograph on page 1495, of Vol. 31, Proceedings of this association.

Conclusions

1. The use of heavy rail in heavy-traffic, high-speed lines reduces the amount of labor necessary to maintain a given standard of track excellence.

2. This reduction is both direct and indirect. The items affected directly include line, surface, gage, joint maintenance and laying rail. The items affected indirectly include tie renewals, cleaning ballast and ballast renewals.

3. Since the labor required for practically every item of track maintenance is affected also by factors that have no relation to the weight of the rail, it is impossible to segregate those factors in such a way that the effect of the heavy rail alone can be evaluated.

4. The magnitude of the economy that can be realized from increasing the weight of rail depends on the relative stiffness of the heavy rail and the lighter rail that it displaces, the volume of traffic, the axle loads and the speed of trains.

5. For lines of high traffic density, the saving in track labor following the installation of 112 and 131-lb. sections in place of sections weighing 100 lb. and lighter may reach 40 percent of the total expenditure for this item. As the volume of traffic decreases, this saving also decreases until a point is reached where considerations other than savings in labor must justify the increase in weight of rail.

Recommendations

That this report be received as information; that the conclusions be adopted for publication in the Manual.

Appendix D

(6) ECONOMIES IN LABOR TO BE EFFECTED THROUGH INCREASED CAPITAL EXPENDITURES

G. M. O'Rourke, Chairman, Subcommittee; W. H. Brameld, Armstrong Chinn, A. C. Harvey, C. H. Paris, H. A. Cassil, E. A. Craft, J. S. McBride, A. E. Perlman, A. A. Woods.

Increased capital expenditures for the items listed below have been reported upon in previous work of your committee, particularly in proceedings for 1938, Vol. 39, page 582. This list includes:

Subsoil drainage.
Driving poles to support settling embankment.
Driving scrap-steel rail piles in soft spots.
Better and greater depth of ballast.
Increased size and length of ties.
Treated versus untreated ties.
Increased weight of rail.
Rail anchors.
Labor saving devices.
Bolt tightening machines.
Power mowing machines.
Automatic pumping plants.
Automatic interlockers.
Cinder hoist.
Flashing light signals at street crossings.

Subsoil Drainage

Additional and more detailed information concerning subsoil drainage has been secured covering installations of perforated corrugated iron pipe.

An installation in Indiana embracing 1,600 ft. of roadway, including three projects, cost $5,900. Maintenance expense per annum before installation was $1,140. During the year following the cost was $32. The saving was $1,108 per year or 18 percent on the investment. Another installation in Indiana is reported to have produced an annual saving of 40 percent on the cost.

An expenditure of $4,660 was made by a railroad in Iowa and the result was that the section gang was reduced from six men to three and these three devote but one day per week to the fill where the eight-inch perforated corrugated iron pipe was installed, whereas the six men worked on it three days a week before the installation. A very troublesome quarter mile of dump was drained with this same kind of pipe at a cost of $3,450. Maintenance cost was reduced from $1,400 to $60 per annum, or a 39-percent saving on the investment.

With reference to economies and other benefits that may be expected from expenditures for roadway drainage, refer to comments and reports in the proceedings listed below:

1938, Vol. 39, p. 320	1934, Vol. 35, p. 348
1938, Vol. 39, p. 562	1933, Vol. 34, p. 132
1938, Vol. 39, p. 565	1932, Vol. 33, p. 304
1937, Vol. 38, p. 173	1932, Vol. 33, p. 330
1937, Vol. 38, p. 357	1932, Vol. 33, p. 377
1936, Vol. 37, p. 141	1931, Vol. 32, p. 169
1935, Vol. 36, p. 1092	1930, Vol. 31, p. 601

On page 601, Vol. 31 of the Proceedings of 1930 will be found references to studies made in the past as far back as 1909.

Driving Cull Ties and Piles in Soft Track

Some information on the driving of piles and cull ties was secured, but the costs were so variable on the different railroads that it is not practicable to report actual labor savings although the various methods have been found to be effective.

Ballast

Relative to the question of economies in labor to be effected through increased expenditures for ballast, information is available in the Proceedings as listed below:

1932, Vol. 33, p. 359	1934, Vol. 35, p. 667
1933, Vol. 34, p. 527	1938, Vol. 39, p. 595

The results of your committee's efforts to secure further information on the subject have been unsatisfactory.

Treated Versus Untreated Ties

While the committee appreciates the fact the use of treated ties does not involve capital expenditures under the accounting rules prescribed by the I.C.C., it was thought that such ties constituted a distinct betterment and involved so large a saving in labor as to warrant the inclusion of the subject in this report. On the basis of 45 cents per tie for labor of placing in the track, the average annual labor cost per mile for placing ties would be as follows:

$$\text{Untreated ties } \frac{3{,}000 \text{ ties}}{8 \text{ years}} \times 45¢ = \frac{3{,}000}{8} \times 45¢, \text{ or } \$168.75$$

$$\text{Treated ties } \frac{3{,}000 \text{ ties}}{20 \text{ years}} \times 45¢ = \frac{3{,}000}{20} \times 45¢, \text{ or } \$\ 67.50$$

Annual labor saving per mile through use of treated ties $101.25

On an middle-western railroad 95 percent of all ties now in the track are treated. The annual renewals per mile per year for the four years 1933 to 1936 inclusive were:

1933 107	1935 147
1934 64	1936 99

The labor costs for installation were:

1933	Per	tie	29 cents	Per	mile	$31.10
1934	"	"	38 cents	"	"	24.07
1935	"	"	38 cents	"	"	55.38
1936	"	"	37 cents	"	"	36.94
Average	"	"	35½ cents	"	"	36.87

The chief engineer of that railroad comments as follows on the possible labor saving:

"Tie labor cost average for the four years as a percentage of the total maintenance of way expense per equated track mile equals $0.0143. This percentage will increase with the number of renewals and a comparison of this figure with those of roads using untreated ties would supply the answer. A check of one road using untreated ties shows this figure to be $0.071."

There is a trend toward larger treated crossties and as this larger size contributes to the longer life of the tie in place, the annual cost of the labor of placing the tie is decreased. The boring and adzing of ties before treatment has been effective in increasing the life span with a resultant saving in labor. Although no definite economies can be allocated, it is well recognized that the use of treated ties has a distinct effect upon the interval between the resurfacing of main tracks.

Tie Plates and Rail Anchors

The investigation conducted by your committee to develop the savings in labor through increased capital expenditures for more and larger tie plates, has not produced statistics by which a good measure of economy may be established. Safety of traffic, as well as economy of labor and material, is involved.

Much the same comment may be made on the results of efforts to secure factual information concerning economies in labor to be effected through increased capital expenditures for rail anchors. Such information as has been obtained was reported in the Proceedings for 1938, Vol. 39, page 584.

Labor Saving Machinery

Due to the depression, loss of business and earnings, and postponement of many activities requiring roadway equipment and labor saving machinery, not much information is available.

The cost of ditching and bank widening with a crawler-type dragline was six cents per yard compared with 34 cents per yard with a steam ditcher and dump cars.

A power jack paid for itself in less than two weeks during restoration work following a washout.

A power wrench, during one summer saved more than twice the cost of the machine. With the power wrench, joints were replaced for seven cents per joint against 18 cents per joint when done by hand.

Each of four power ballast cribbing machines cribbed an average of 22.76 miles in stone and crushed slag ballast during the 1937 season. The expense, per machine, including operating costs, repairs, depreciation and interest on investment, was $8,000. To do the same work by hand cost $11,000. The net annual saving effected by the use of the machine is $3,000, with a labor saving of approximately $7,000.

Economies effected by the use of machinery in rail laying will depend considerably upon the ability to provide a whole season's work for the machines; and where a rail relaying program of several hundred miles is contemplated, savings from the use of machines will considerably more than meet interest on the investment, and provide a much more satisfactory job. Seven men with a self-propelled rail crane will do as much as

13 men with hand work. The saving of 60 man-hours per day equals about $18. There is also less likelihood of injuries from back strain, rails let down on feet, etc.

Eight men operating adzers and grinders, compared to 12 men doing hand adzing, means a saving of 40 man-hours per day.

Ten men with spike pullers and pulling spikes which machines could not reach, compare with 16 men pulling all spikes by hand, thus saving 60 man-hours per day.

Two men with a bolt remover, two men cutting bolts with a torch, two men with a bolting machine putting in bolts; compared with six men cutting bolts both in and out of track, and six men installing and tightening bolts in new rail results in a saving of 60 man-hours per day. Due to each joint being disconnected, it is possible to save four men per day in lining out old rail.

Bridges and Buildings

The economies in labor that may be effected through increased capital expenditures for bridges, buildings and other structures were submitted by the chief engineer of one of our trunk line railroads and are presented here as received from him:

> It is thought that the economy in labor to be effected through increased capital expenditures for bridges, buildings and other structures must be computed and the merits thereof weighed in each specific case. As an example, it is unquestionably true that coaling of locomotives through a modern coaling plant requires less labor than hand coaling from a car on an adjacent track. However, the question of the justification for the expenditure for any coaling plant, and the question of whether the plant should be a simple flight conveyor or a large plant with large storage capacity must be decided after consideration of many factors, such as, frequency of trains, speed of trains, class of traffic and many other conditions.
>
> Similarly, under given conditions it might be possible to construct a brick building for $10,000 and an approximately equal frame building for $7,500. If in each case the labor cost was one-half of the total and the estimated service lives of the brick and frame structures were estimated as 50 years and 30 years, respectively, the annual cost of the labor required for the construction would be $100 for brick, $125 for frame. Thus, from the standpoint of labor cost alone the greater capital expenditure results in a lesser annual cost.

In bridge and building maintenance and renewal work, particularly, large economies are possible in the cost of both labor and material if such work can be handled on a predetermined program basis and capital expenditures authorized to suit the routine of requirements of maintenance renewals.

Signals and Interlockers

The economies in labor to be effected through increased capital expenditures for highway and street crossing signals, interlockers and block signals are evident when such installations supplant crossing watchmen, gate tenders and flagmen.

It has been found after three years of effort that little definite and satisfactory information can be obtained by which to show the savings in labor which can be obtained by capital expenditures. Specific cases of high maintenance labor costs can be studied and the actual maintenance costs established and reliable estimates made of savings possible by investment of capital. However, in many phases of railroad maintenance, so many factors are involved that the justification of capital expenditures to effect savings in labor costs must be governed by good judgment and a personal knowledge of actual local conditions rather than statistical information.

Your committee's efforts in this connection have undoubtedly been handicapped by the continual financial stringency effecting the railroads which has restricted progress in this direction due to the limitations on funds available for capital expenditures which were not immediately imperative.

Conclusion

The studies of your committee show conclusively that marked economies can be obtained by certain capital expenditures and should be given consideration whenever funds are available.

It is recommended that this report be received as information.

Appendix E

(7) SANITARY PROVISIONS IN CAMPS AND CARE FOR HOUSING LABOR

J. B. Martin, Chairman, Subcommittee; C. W. Baldridge, F. J. Bishop, W. C. Brown, F. L. Guy, W. S. Hanley, H. H. Harsh, E. T. Howson, F. H. Rothe, C. R. Wright. (Collaborating with Committee 13—Water Service, Fire Protection and Sanitation—H. W. Van Hovenberg).

Railroads require and employ large numbers of men for the maintenance of the property and for various construction jobs. These employees are distributed over many states, in cities, towns, villages and at isolated rural points. The location of the work, lack of local labor or nature of the work, often makes it necessary for the railroad, in the absence of other facilities, to house, feed and furnish the other necessities for these employees in both large and small numbers.

The nature and location of the work determines whether buildings or cars are used for housing purposes. Some camps and mobile outfits are year round homes for many employees, such as bridge, building, signal and track men, while others are seasonal and more or less temporary. With the wide distribution of these camps, the number of men to be housed and cared for, and with every variety of climate, there will necessarily be some variation in how to provide proper sanitation economically; however, the essentials of good sanitation are much the same in all sections of the country. Health safeguards, pure water and cleanliness are just as essential in one section of the country or location as another.

To quote from the Manual, p. 22–2, Economics of Railway Labor, Section C "Employees" paragraph 9—"Satisfactory working conditions, including the provision of sanitary and agreeable facilities while on duty; and where required clean and comfortable rest houses, rest rooms, and dining rooms, with a sufficient quantity of wholesome food, should be in effect on all roads."

These men are employees housed on railroad property, and the railroad has an obligation to see that they are comfortably housed, well fed and their health and well-being protected by the proper sanitary safeguards.

While your committee knows of no way to arrive at a dollar-and-cent value of camp sanitation, it is the consensus of the officers of those railroads where this subject has been studied, and both the equipment and sanitary conditions have been improved, that it is economical to provide sanitary camps. Clean healthful camps, well disciplined, attract good men. Men fed clean appetizing food will be more efficient, and a good boarding table will attract good workmen. A good night's rest is necessary for hard

manual labor and good clean recreation and pleasant surroundings will make and keep men contented and interested. Economy is realized from a better class of workmen, reduced turnover, greater production and efficiency, and a reduction in time lost because of sickness and quarantines.

Your committee considers the assignment that of presenting for the guidance of the railroads the best methods and regulations for maintaining economically, clean, healthful camps with pleasant surroundings that will attract and keep in the service desirable and ambitious men.

The subject of sanitation has been given considerable study by Committee 13—Water Service, Fire Protection and Sanitation, which has presented reports and papers that contain material pertinent to the subject of this report. Much of this material has been placed in the Manual.

The following is a reference to the subjects covered:

General:

Vol. 30, 1929 Proceedings, pp. 207–209. "The Association's Opportunity for Promoting Railway Sanitation" by H. W. Van Hovenberg.

Vol. 35, 1934, Proceedings, pp. 637–639. "Essentials of Mosquito Control" by H. W. Van Hovenberg.

Water for Drinking Purposes:

Manual p. 13–67.

Vol. 39, 1938 Proceedings, p. 202.

Vol. 39, 1938 Proceedings, p. 207.

Vol. 21, 1920 Proceedings, pp. 54, 1347.

Sewage Disposal Where Sanitary Facilities Are Not Available:

Manual p. 13–74.

Vol. 37, 1936 Proceedings, pp. 397, 967.

Vol. 34, 1933 Proceedings, pp. 92–100.

Disinfectants, Fumigants and Cleaning Materials:

Manual p. 13–75.

Vol. 37, 1936 Proceedings, pp. 398, 967.

Vol. 35, 1934, Proceedings, pp. 640–643.

These reports and papers cover sewage disposal where sanitary facilities are not available, and types of toilets for both permanent and mobile camps; mosquito control; disinfectants; fumigants and cleaning materials; the handling of water and ice; and the clarification and disinfection of small drinking water supplies.

The following additional sanitary provisions in camps and cars for housing labor are recommended:

(a) *Food:* Meats and other foods should be of standard quality and should conform to U. S. inspection and the pure food laws.

There should be sufficient variety to make the meals inviting and with a consistent and regular amount of fresh meats and vegetables.

Perishable foods should be stored in refrigerators of sufficient capacity. Refrigerators should be thoroughly cleaned at frequent intervals. Other foods should be stored in metal containers which are accessible and easily cleaned, and off the floor; preferably on slat shelves.

Food should be prepared and served in a cleanly, appetizing manner, with dishes and utensils that are clean and that can be kept clean.

All garbage should be placed in metal containers with tight-fitting covers, and should be disposed of daily, if possible. All waste metal containers, tin cans, etc., should be thoroughly cleaned and put in fly proof containers for disposal. In the absence of a regular garbage collection, it should be disposed of by complete burial, or by the use of a portable incinerator. This regulation is to apply where there is a considerable volume and its disposal presents a considerable problem.

(b) *Dishwashing:* Dishes should be washed with hot water, using plenty of soap and with the addition of some other detergent if necessary. They should be thoroughly rinsed with boiling water.

(c) *Floors, etc.:* Floors, tables and sinks in kitchens and dining rooms should be scrubbed daily. Dining table should be covered with mosquito netting between meals.

(d) *Linen:* Linens used in the handling of food and dishwashing should be kept clean and in good order. They should be laundered regularly and should be boiled. They should be stored in clean and dustproof lockers between usings.

(e) *Water for Drinking and Culinary Purposes:* All water used for drinking and culinary purposes should be secured from a certified source and if it becomes necessary, in an emergency, to secure water from sources that are not certified, it should be disinfected with some approved water disinfectant, preferably calcium hypo-cholrite. (See Manual,—Chapter 13).

Once each year storage tanks should be thoroughly drained and sterilized with hot water and soda, or with steam only, if necessary, after which they should be rinsed with clean cold water four times if hot water and soda are used, or rinsed twice if steam is used.

At least once a week drinking water tanks should be thoroughly scalded out with hot water or clean steam, and then rinsed with clean cold water. If hot water or clean steam is not available, drinking water tanks should be cleaned by using a small stiff broom and a small amount of suitable cleaning material. Tanks cleaned in this manner should be thoroughly rinsed with clean water three times before they are filled for use. Tanks should be provided with tight covers that are securely fastened to prevent the access of dirt or insects.

(f) *Toilet Facilities:* See Manual, Chapter 13.

(g) *Shower, Wash and Toilet Car:* Where showers, wash or toilet facilities are provided, they should be kept clean.

(h) *Insects and Rodents:* See Manual, Chapter 13. All windows and doors should be screened with 16-mesh wire. Screen doors should swing out and doors, windows and screens should fit tightly and be substantial enough to stay in place without sagging or warping. All cars should be kept free of insects, rodents and vermin by disinfecting or fumigating as often as necessary.

Cleaning is important and should be done by competent help, supplied with the proper cleaning materials. A spray made with pyretheum and white kerosene will be found useful in controlling house flies.

Gaseous fumigation is a common method of eliminating insects and vermin and hydrocyanic gas is used generally. This product can be secured in various forms and the recommendations in the Manual, p. 13–75 and AREA proceedings should be followed, as well as the manufacturer's directions. Where local ordinances provide regulations for the use of hydrocyanic acid gas and require licensed operators, these regulations should be observed. Where it is practical and tight buildings are available, such as old shop buildings or dry kilns, cars should be run into them for fumigation. This will insure more effective results.

The following quoted from Railway Engineering and Maintenance for May, 1931, p. 469, gives useful information for fumigating with hydrocyanic acid gas:

Fumigation should not be undertaken when the temperature is below 70° F., as many insects are dormant at 55° F. or less, and best results will be obtained at 80° F. or higher. Fumigation should not be attempted on windy days since leakage of gas occurs in even the tightest structure.

If the structures are badly infected it may be desirable to fumigate a second time, ten days or two weeks after the first, in order to secure thorough results.

In general the period of exposure is three hours, although for certain insects, such as moths and cockroaches, an exposure of about four hours is required.

In tightly constructed buildings or cars all that is necessary is to close all doors, windows and ventilators for sealing. In outfit cars more preparation is required to prevent air leakage. Papers or sacks should be stuffed into the stove pipes and all exterior cracks and crevices should be sealed, and any broken window panes should be covered by means of paper applied with flour and water paste.

After period of fumigation is completed, all doors and such windows as can be opened from the outside should be opened for not less than thirty minutes before room is entered for the purpose of opening the remaining windows. On still days a longer time may be required.

No person should be allowed to remain in the room until the odor of gas can no longer be detected.

Hydrocyanic acid has a distinct and readily recognized odor which the operator should be taught to regard as a definite danger signal. This odor is not easily detected however if the sense of smell is impaired. For this reason operators who have colds or are suffering from other disabilities which affect their sense of smell should not be allowed to engage in fumigating work until they are restored to normal physical condition.

Fumigators should be forbidden to place the fumigant, or open buildings or cars after fumigation unless an assistant is present.

No one should stand in the draft that emanates from the building or car during the period of ventilation.

Prolonged contact with the gas even when well diluted is likely to produce headache or a feeling of dizziness. Since the inhalation of ammonium salts acts as an antidote, any person feeling any effect of contact with the gas should get into the open air and inhale ammonium salts immediately.

While fumigation is in progress a guard should be left on duty during the entire period of exposure and ventilation. All entrances should be locked and as an added precaution placards should be displayed at every door warning against attempts to enter. After all preparations are completed, but before placing the fumigant, a thorough search should be made, particularly of sleeping quarters, to insure that no one is left in the building or car to be fumigated.

(i) *Medical Inspection:* Laborers and camp personnel, especially those handling food, should be given thorough physical examination when hired and should have periodical examinations afterwards.

(j) *Laundry:* Blankets should be laundered frequently and all bed linens should be changed weekly. Matresses should be fumigated when buildings or cars are fumigated.

(k) *Housekeeping:* Regulations governing the camp should be posted in each room or car. A regular system of inspection should be inaugurated to insure that the

.....RAILROAD

MONTHLY INSPECTION OF BOARDING CARS AND CAMPS

Department..... No..... Extra Gang.....
Foreman..... Located at.....
Commissary Clerk..... Cook.....
Waiter..... Inspected by.....
Date..... .... No. of Men in Camp.....

		PERFECT:	ALLOWED
EQUIPMENT—HOUSEKEEPING:			
(a)	Cond. of premises (5).... (Absence of Commissary and Kitchen refuse)	5	
(b)	Cleanliness of floors (5).... Tables (5).... Benches (3).... Walls (1).... Ceiling (2).... Windows (1)	17	
(c)	Storage Facilities for food supplies (10).... (Refrigerators, flour and meal bins, food protected from weevils and rats in store room)	10	
(d)	Condition of condiment containers (3)	3	
(e)	Cond. of implements and utensils for cooking (5).... Serving (5)	10	
(f)	Cleanliness of lavatory facilities (5)	5	
(g)	Dishwashing facilities (5).... (Hot water boiler)	5	
QUALITY OF FOOD:			
(h)	Quality of food supplies (10)	10	
HANDLING AND PROTECTION:			
(i)	Personal cleanliness of employes (5)	5	
(j)	Handling of food supplies, Prep. (10).... Serving (5)....	15	
(k)	Absence of flies (10).... Insects and rodents (5)..... (Due to doors NOT standing open. If flies present due to defective screens, so note in this space).	15	
		100	
EQUIPMENT—PHYSICAL CONDITION:			
(a)	Condition of: Floors (5).... Tables (5).... Benches (3).... Walls (5).... Ceiling (2).....	20	
(b)	Light (5).... Ventilation (5).....	10	
(c)	Cond. of screens, overdoors, windows and springs on doors (15)	15	
(d)	Water tight roofs (10)	10	
(e)	Lavatory facilities (10)	10	
PHYSICAL CONDITION OF WATER SUPPLY:			
(f)	Approved source (10)	10	
(g)	Cond. of tanks and containers—Cleaned as required (5).... Protection against contamination (5)	10	
(h)	Method of handling water from tanks (10)	10	
PREMISES:			
(i)	Condition of premises (5) ..... (Waste paper, clothing and other refuse around cars and right of way)	5	
		100	

REMARKS:

camp is clean and in good order, and that doors, windows and screens are in place. All rubbish and litter around the camp or cars should be picked up and disposed of daily. Grounds should be kept in a neat and orderly condition. Weeds in the vicinity of camps or cars should be cut.

(l) *Location:* Camps should be located where they will be as quiet as possible, without excessive heat, and with regard for the safety of the occupants.

(m) *Policing:* Some one person should be designated to see that order is maintained and that regulations are observed. A time should be specified for lights out and quiet.

(n) *Inspection:* Camps and cars should be inspected by some division officer at least monthly to see that all regulations are being observed, and as an aid in stimulating interest in sanitation, cleanliness and orderliness it is recommended that a form be used in this inspection on which each item is rated, on a percentage basis, with a view of bringing about a constant improvement of conditions, as well as uncovering the existence of any lax methods. (A suggested form of report is submitted as information.)

Recommendations

That subdivisions (a) to (n), both inclusive, be accepted for publication in the Manual; that paragraphs 7 and 9, page 22–9, Manual, be deleted; that the suggested form of inspection report be received as information.

Appendix F

(10) THE ECONOMIC RELATION BETWEEN SUPERVISION AND LABOR

L. L. Adams, Chairman, Subcommittee; F. J. Bishop, J. I. Catherman, R. R. Cummins, H. H. Harsh, G. M. Magee, J. A. Parant, R. L. Sims, W. H. Vance, C. R. Wright.

Your committee reported on the assignment, "The Economic Ratio of Supervision to Labor", in 1929, this report appearing in the Proceedings for that year, Vol. 30, page 1139.

Due to drastic reductions in maintenance of way forces and changes in their organization since 1929, it was deemed advisable to make a further study at this time in an endeavor to develop, if possible, what would be the most economical ratio to maintain between labor and supervision.

Your committee has assembled data from representative railroads throughout the United States to show the number of man-days of labor and supervision used in the maintenance of ways and structures for the years 1929 and 1937. From this information, a statement was prepared showing, in percentages, the reductions made in 1937 as compared with 1929, and this statement is submitted as an addendum to this report.

The statement shows that all roads have made marked reductions in maintenance of way labor since 1929 ranging from 27 percent to 66 percent. Even with this reduction, a similar ratio between supervision and labor has been maintained. To accomplish this result it has been necessary to make changes in organization, that is, lengthen sections and organize large gangs, housed in cars, to perform general maintenance work such as surfacing track, laying rail, renewing ties and maintaining structures.

This reduction and the changes in organization have clearly demonstrated that supervision has two limitations; (1) the number of men that a foreman, or other supervisory man, can work economically; (2) the miles of track or number of structures that can be inspected and maintained safely. There is no doubt that on most of the railroads the second limitation exists at the present time, which was not the case in 1929. Therefore, it may be possible to increase the number of man-days at the present time without making a proportionate increase in supervision.

Due to divergent local conditions, a direct comparison cannot be made between the various railroads, but the results obtained in a general way by all railroads in the past nine years furnish a basis from which general conclusions can be reached. The information given in the addendum affords a basis of study that should aid in determining, in a general way, what may be accomplished to improve the economic relation between supervision and labor.

Conclusions

(1) The ratio of supervision to labor is an individual problem to each railroad.
(2) The ratios in 1929 and 1927 were not the most economical in every respect.
(3) General economic conditions will always affect the ratio of supervision and labor.

It is recommended that this report be received as information.

Appendix G

(11) THE EFFECT OF SUDDEN FLUCTUATIONS IN MAINTENANCE EXPENDITURE ALLOWANCES ON MAINTENANCE COSTS

Armstrong Chinn, Chairman, Subcommittee; L. L. Adams, W. C. Brown, W. S. Hanley, H. E. Kirby, G. M. O'Rourke, C. H. Paris, R. L. Sims, H. M. Stout.

Maintenance men recognize that sudden fluctuations in maintenance expenditure allowances, either up or down, exert an adverse effect on maintenance costs, but the committee has been unable to develop any way in which this may be determined. Some of the effects of sudden fluctuations in maintenance expenditure allowances are as follows:

Adverse Effects of Sudden Increases

1. Unit costs increase and the quality of the work decreases when inexperienced men are employed.

2. Costs increase when insufficient time is available in which to organize for the most economical procedure.

3. Costs increase when gangs are not supplied with the tools, machines and materials necessary to perform their work efficiently.

Adverse Effects of Sudden Decreases

1. When trained employees are laid off and find work elsewhere, unit costs are increased when forces are restored and untrained men employed.

2. Costs are increased by the re-handling and storage of tools, equipment and materials previously distributed.

3. Costs increase when a program is deferred and work of a temporary nature, which is later lost, is substituted to carry until the program can be resumed.

General

A stabilized labor force, free from sudden fluctuations in maintenance expenditure allowances, will help hold maintenance costs to a minimum for the following reasons:

1. It permits a specific program to be carried through to completion in the most economical manner.

2. It permits employees to be trained for the work they are to perform; trained men do more and better work than untrained men.

ECONOMICS OF RAILWAY LABOR - LABOR vs. SUPERVISION - 1937 vs. 1929 - MAN DAYS ACTUALLY WORKED

Railroad	Percent Reduction under 1929																Relation Labor vs. Supervision				
	Roadmasters Supervision	B&B Foremen	Sig. & Tel. Fmen & Insps.	Extra Gang Foremen	Section Foremen	Total Supervision	B&B Carpenters	B&B Painters	B&B Plumbers, Bricklayers, etc.	Signal, Linemn., Helpers, Etc.	Skilled Trade Helpers & AsstS.	Steam Equipment Operators	Steam Equipment Opr. AsstS.	Pump Equipment Operators	Extra Gang Laborers	Section Laborers	Other M. of W. Labor	Total Labor	% Labor 1929 to Total	% Labor 1937 to Total	% Supervision 1929 to Total	% Supervision 1937 to Total	Total percent reduction in Man Days 1937 compared with 1929
A	21	42		68	32	35	49	12+	100		19	60	69	34	65	38	33	43	83	84	17	16	42
B	48	49	62	25	52	50	59	30	33	36	12	14	72	42	27	69	49	59	88	86	12	14	58
C	51	40		70	39	43	37	88	87		38	59	71	53	62	44	50	47	87	86	13	14	46
D	8	27		58	19	20	27	1+	84		18	9	9	72	31	28	8	28	84	83	16	17	27
E	14	29+		14+	60	47	16	235+	27		427+	37	34	62	2+	46	32+	34	82	85	18	15	36
F	16	52	40	78	35	38	48	79	89	22	48	33	34	60	78	49	44	51	84	80	16	20	49
G	35	43		78	19	29	50	76	41		17+	57+	32+	46	78	46	34	50	88	84	12	16	47
H	39	20		77	49	48	65	100	27		74	6+	45	56	62	57	34	57	85	83	15	17	55
I	10	46		48	23	25	55	62	82		49	40	37	50	39	37	36	40	81	78	19	22	37
J	42	52		71	50	51	61	64	55		66	15	36	37	65	60	28	59	85	83	15	17	58
K	23		60	3	39	36	60		62	47	100	14	48	66	3	46	65	35	88	88	12	12	35
L	26	55		74	1	15	64				65	18	66	67	77	51	84	62	92	83	8	17	58
M	22	36		35	48	42	50	77	30		43	30	43	38	11	59	31	45	82	82	18	18	44
N	37	44		17	35	33	44				48	12+	15	67	19	45	30	40	85	84	15	16	38
O	20	40	34	51	48	45	43	65	27	40	3	18	44	44	59	38	52	41	82	83	18	17	42
P	4	28		4+	33	30	36	58	70		27	32+	41	33	45	54	2	49	84	78	16	22	46
Q	27	55		24	36	36	44	52	11+		67	33	34	60	44	52	71	49	82	78	18	22	45
R	50	45		46	53	50	45	41	23		32	33		88	69	46	17	52	84	84	16	16	52
S	29	46		43	47	45	53	49	38		8	97+	94	95	39	57	15+	49	86	85	14	15	49
T	24	22		20	24	23	63	49	69		41	20	73	96	48	72	82	64	86	75	14	25	58
U	5+	15		50	16	17	46	34	29		50	17	40	49	61	40	41	45	80	72	20	28	39
V	22	17		44	18	22	37	24	74		27	32	77	63	52	46	24	46	90	87	10	13	44
W	43	50	21	65	35	49	52	77	52	22	59	33	60	69	72	45	26	51	85	82	15	18	50
X	13	29		58	6	14	33	12+	25		5	54+	22	28	30	43	17+	35	89	86	11	14	33
Y	37	16		48+	35	29	31	2	20		16	16+	141+	85	15+	52	8	39	83	81	17	19	37
Z	21	34		80	8	12	49	6	5		82	58	100	93	60	41	10+	43	81	74	19	26	37
AA	100	8		76	51	57	23	-			64+	59			70	72	35	68	88	85	12	15	66
Average	29	35		47	34	34	46	45	47		37	23	47	60	47	49	31	47	85	82	15	18	45

+ Increase

METALLURGICAL LIBRARY

3. It enables a road to obtain a better class of employees, as the best men seek and eventually find steady employment.

4. It eliminates lost time and lowered efficiency, for maintenance forces fluctuate with fluctuations in maintenance expenditure allowances, and unit costs increase when gangs are organized and started out, or when they are laid off or otherwise disturbed during the progress of their work.

5. A stabilized force works more efficiently than one employed intermittently.

6. Administrative costs are increased when there is a heavy labor turnover.

7. It permits better utilization of work equipment, as an undisturbed program makes it possible to employ the equipment to best advantage at all times.

8. It permits materials to be delivered to the job when desired, thus eliminating delays to gangs waiting for materials while keeping stocks at the minimum.

Your subcommittee calls attention to a previous report on this general subject found in the last two paragraphs on page 492, the sixth paragraph on page 494 and the first paragraph on page 495 of Volume 29 of the Proceedings.

Conclusion

Sudden fluctuations in maintenance expenditure allowances increase labor costs and adversely affect the quality of the work.

It is recommended that the conclusion be published in the Manual.

Appendix H

(1) REVISION OF MANUAL

F. S. Schwinn, Chairman, Subcommittee; L. L. Adams, C. W. Baldridge, H. A. Cassil, Armstrong Chinn, E. T. Howson, H. E. Kirby, J. B. Martin, J. S. McBride, G. M. O'Rourke, W. H. Vance.

Your committee has given consideration to the several recommended conclusions for publication in the Manual, and subject to the approval of such conclusions as presented under the individual subjects, desires to recommend such publication in the following manner:

(A) Conclusions in Appendix C to be added on page 22–4, Manual, as a new subsection as follows:

H. WEIGHT OF RAIL

(a) The use of heavy rail in heavy-traffic, high-speed lines reduces the amount of labor necessary to maintain a given standard of track excellence.

(b) This reduction is both direct and indirect. The items affected directly include line, surface, gage, joint maintenance and laying rail. The items affected indirectly include tie renewals, cleaning ballast and ballast renewals.

(c) Since the labor required for practically every item of track maintenance is affected also by factors that have no relation to the weight of the rail, it is impossible to segregate those factors in such a way that the effect of the heavy rail alone can be evaluated.

(d) The magnitude of the economy that can be realized from increasing the weight of rail depends on the relative stiffness of the heavy rail and the lighter rail that it displaces, the volume of traffic, the axle loads and the speed of trains.

(e) For lines of high traffic density, the saving in track labor following the installation of 112 and 131-lb. sections in place of sections weighing 100 lb. and lighter may reach 40 percent of the total expenditure for this item. As the volume of traffic decreases, this saving also decreases until a point is reached where considerations other than savings in labor must justify the increase in weight of rail.

(B) The present title of Section III on Page 22–9, Manual, reading "Plans for Outfit Cars for Maintenance of Way Department Employes", shall be made to read:

Housing Maintenance of Way Employees

(C) Below the new title of Section III on Page 22–9, there shall be the following:

A. SANITARY PROVISIONS

The following sanitary provisions in camps and cars for housing labor are recommended:

(D) Immediately under the preceding introductory sentence there should follow the recommended additions given in Appendix E as subdivisions (a) to (n), both inclusive, and reading:

(a) *Food.*—Meats and other foods should be of standard quality and should conform to U. S. inspection and pure food laws.

There should be sufficient variety to make the meals inviting to all and with a consistent and regular amount of fresh meats and vegetables.

Perishable foods should be stored in refrigerators of sufficient capacity. Refrigerators should be thoroughly cleaned at frequent intervals. Other foods should be stored in metal containers which are accessible and easily cleaned, and off the floor; preferably on slat shelves.

Food should be prepared and served in a cleanly, appetizing manner, with dishes and utensils that are clean and that can be kept clean.

All garbage should be placed in metal containers with tight fitting covers, and should be disposed of daily if possible. All waste metal containers, tin cans, etc., should be thoroughly cleaned and put in fly proof containers for disposal. In the absence of a regular garbage collection, it should be disposed of by complete burial or by the use of a portable incinerator. This regulation is to apply where there is a considerable volume and its disposal presents a considerable problem.

(b) *Dishwashing.*—Dishes should be washed with hot water, using plenty of soap and with the addition of some other detergent if necessary. They should be thoroughly rinsed with boiling water.

(c) *Floors, etc.*—Floors, tables and sinks in kitchens and dining rooms should be scrubbed daily. Dining table should be covered with mosquito netting between meals.

(d) *Linen.*—Linens used in the handling of food and dishwashing should be kept clean and in good order. They should be laundered regularly and should be boiled. They should be stored in clean and dustproof lockers between usings.

(e) *Water for Drinking and Culinary Purposes.*—All water used for drinking and culinary purposes should be secured from a certified source and if it becomes necessary, in an emergency, to secure water from sources that are not certified, it should be disinfected with some approved water disinfectant, preferably calcium hypo-chlorite. (See Manual, Committee 13).

Once each year storage tanks should be thoroughly drained and sterilized with hot water and soda, or with steam only if necessary, after which they should be rinsed with clean cold water four times if hot water and soda are used, or rinsed twice if steam is used.

At least once a week drinking water tanks should be thoroughly scalded out with hot water or clean steam, and then rinsed with clean cold water. If hot water or clean steam is not available, drinking water tanks should be cleaned by using a small stiff broom and a small amount of suitable cleaning material. Tanks cleaned in this manner should be thoroughly rinsed with clean water three times before they are filled for use. Tanks should be provided with tight covers that are securely fastened to prevent the access of dirt or insects.

(f) *Toilet Facilities.*—(See Manual, Chapter 13).

(g) *Shower, Wash and Toilet Car.*—Where showers, wash or toilet facilities are provided they should be kept clean.

(h) *Insects and Rodents.*—(See Manual, Chapter 13). All windows and doors should be screened with 16 mesh wire. Screen doors should swing out and doors, windows and screens should fit tightly and be substantial enough to stay in place without sagging or warping. All cars should be kept free of insects, rodents and vermin by disinfecting or fumigating as often as necessary.

Cleaning is important and should be done by competent help, supplied with the proper cleaning materials. A spray made with pyretheum and white kerosene will be found useful in controlling house flies.

Gaseous fumigation is a common method of eliminating insects and vermin and hydrocyanic gas is used generally. This product can be secured in various forms and the recommendations in the Manual, Page 13–75, and AREA Proceedings should be followed as well as the manufacturer's directions. Where local ordinances provide regulations for the use of hydrocyanic acid gas and require licensed operators, these regulations should be observed. Where it is practical and tight buildings are available, such as old shop buildings or dry kilns, cars should be run into them for fumigation. This will insure more effective results.

(i) *Medical Inspection.*—Laborers and camp personnel, especially those handling food, should be given thorough physical examination when hired and should have periodical examinations afterward.

(j) *Laundry.*—Blankets should be laundered frequently and all bed linens should be changed weekly. Mattresses should be fumigated when buildings or cars are fumigated.

(k) *Housekeeping.*—Regulations governing the camp should be posted in each room or car. A regular system of inspection should be inaugurated to insure that the camp is clean and in good order, and that doors, windows and screens are in place. All rubbish and litter around the camp or cars should be picked up and disposed of daily. Grounds should be kept in a neat and orderly condition. Weeds in the vicinity of camps or cars should be cut.

(l) *Location.*—Camps should be located where they will be as quiet as possible without excessive heat, and with regard for the safety of the occupants.

(m) *Policing.*—Some person should be designated to see that order is maintained and that regulations are observed. A time should be specified for lights out and quiet.

(n) *Inspection.*—Camps and cars should be inspected by some division officer at least monthly to see that all regulations are being observed, and as an aid in stimulating interest in sanitation, cleanliness and orderliness, it is recommended that a form be used in this inspection on which each item is rated, with a view of bringing about a constant improvement of conditions, as well as uncovering the existence of any lax methods.

(E) Below the foregoing there shall be the following:

B. PLANS FOR OUTFIT CARS

1934

(F) There shall then follow all matter appearing on Page 22–9 below the year 1934, excepting that Paragraphs 7 and 9 shall be deleted and the remaining numbered paragraphs shall be lettered consecutively from (a) to (h).

(G) Conclusion in Appendix G, reading:

(e) Sudden fluctuations in maintenance expenditure allowances increase labor costs and adversely affect the quality of the work.
—shall be added on Page 22–4, Manual, as Paragraph (e) of Subsection G, Section 1.

(H) Careful consideration has been given to the report on Economics of Methods of Weed Killing given in Appendix A and in Proceedings Vol. 37, Page 236. It was decided that these reports contained valuable Manual material which should be included on Page 22–4, or immediately following, under Section 1 and new Subsection "I. Weed Control". The matter here recommended is:

I. WEED CONTROL

The elimination of weeds and other vegetation from the roadbed is essential to the economical maintenance of track. The control of weeds on the right-of-way contributes to orderly policing and affords an index of efficient maintenance.

In the track, the elimination of vegetation facilitates drainage, increases the life of ties, reduces the fouling of ballast and otherwise decreases the cost of track maintenance. On the right-of-way, the control of weeds improves the view, facilitates activities, reduces the fire hazard and improves appearances.

Weeds should be destroyed at that period in their growth that is most effective in preventing regrowth or reproduction. In general, this is in the early part of their seeding stage.

The greatest economy is effected by reducing to the minimum the amount of hand weeding through the use of mechanical and chemical aids, the relative economy of which varies with the character and density of the weed growth and other local conditions.

On the right of way, economy of maintenance may be frequently promoted by smoothing to permit the operation of mowing machines. It is also economical after smoothing the right of way to seed it with grass adapted to the locality to retard the growth of weeds and minimize soil erosion.

REPORT OF SPECIAL COMMITTEE ON WATERPROOFING OF RAILWAY STRUCTURES

J. A. Lahmer, *Chairman;*
F. E. Bates,
G. E. Boyd,
C. H. Chapin,
A. C. Copland,
A. C. Irwin,
L. H. Laffoley,
F. J. Pitcher,
G. E. Robinson,
A. L. Sparks,
F. P. Turner,
L. W. Walter,
H. T. Welty,
C. A. Whipple,
O. G. Wilbur,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual—

AREA current specifications for membrane waterproofing include specifications for plastic cement having an asphaltic base, and producers of coal tar waterproofing have suggested that these specifications should also provide for the use of plastic cement having a coal tar base. This is receiving attention and it is expected that a revision of the Manual to cover it will be completed next year.

2. Waterproofing and dampproofing of railway structures—

In November, 1937, the American Society for Testing Materials requested that the AREA comment on a number of that society's revised specifications, including D 449–37T, which is a revision of D 144–25 covering asphalt for saturant and mopping in connection with membrane waterproofing for use above ground. The request was referred to this committee for report.

Both the former ASTM specification D 144–25 and current ASTM specification D 449–37T permit a somewhat lower grade of asphalt than current AREA specification, the principal differences being in the ductility requirements as shown below:

	D 144–25	*D 449–37T*	*AREA*
Ductility at 77 deg. F.	Minimum of 15	Minimum of 15	Minimum of 20
Ductility at 40 deg. F.	None required	None required	Minimum of 4

The members of this committee are opposed to lowering the ductility requirements on the ground that this would admit too wide a range of asphalt. We also believe that a ductility requirement at 40 deg. F. is necessary as an indication of behavior of asphalt at low temperature. Consideration of this matter will be continued. The ASTM has indicated that its committee will make a further study of specification D 449–37T with the hope of preparing a specification which will be acceptable to the AREA, the Federal Specifications Board, the American Association of State Highway Officials, and the ASTM.

The Special Committee on Waterproofing of Railway Structures,
J. A. Lahmer, *Chairman.*

Bulletin 408, January, 1939.

REPORT OF SPECIAL COMMITTEE ON IMPACT

J. B. Hunley, *Chairman;*
O. F. Dalstrom,
S. F. Grear,
Meyer Hirschthal,
C. S. Johnson,
A. N. Laird,
P. G. Lang, Jr.,
B. R. Leffler,
J. A. Newlin,
Geo. E. Robinson,
C. P. Schantz,
F. E. Turneaure,
W. M. Wilson,
Committee.

To the American Railway Engineering Association:

Your Committee reports as follows:

Owing to the fact that, during the past year, neither funds to conduct additional impact tests, nor force to analyze existing data, were available, no progress can be reported on any of the subjects assigned to the Committee.

It is recommended that the following subjects, previously assigned, be continued, with the hope that the necessary equipment and personnel will soon be provided.

1. Tests of short steel spans with open floor, together with effect of inequalities of track and effect of worn wheels on such track.

2. Tests of steel spans with ballasted deck, including spans with precast and poured-in-place concrete decks; also tests on ballasted decks with timber floor; particular attention to be given to the damping due to the type of deck and the track ballast.

3. Tests of dynamic shear in girder spans and truss spans.

4. Tests of impact in columns and hangers of steel spans.

5. Tests of rigid frame structures of steel and concrete.

THE SPECIAL COMMITTEE ON IMPACT,
J. B. HUNLEY, *Chairman.*

Bulletin 408, January, 1939.

REPORT OF COMMITTEE 15—IRON AND STEEL STRUCTURES

R. A. Van Ness, *Chairman;*
James Aston,
F. E. Bates,
J. E. Bernhardt,
R. N. Brodie,
A. W. Carpenter,
C. H. Chapin,
O. F. Dalstrom,
R. P. Davis,
Herbert Ensz,
W. G. Grove,
G. A. Haggander,
Shortridge Hardesty,
C. S. Heritage,
O. E. Hovey,
Jonathan Jones,
A. R. Ketterson,
A. M. Knowles,
P. G. Lang, Jr.,
B. R. Leffler,
H. S. Loeffler,
F. M. Masters,
C. H. Mercer,
O. K. Peck,
F. J. Pitcher,
Albert Reichmann,
O. E. Selby,
T. C. Shedd,
C. S. Sheldon,
I. L. Simmons,
J. B. Hunley, *Vice Chairman;*
C. E. Sloan,
S. M. Smith,
G. L. Staley,
H. C. Tammen,
G. H. Tinker,
G. H. Trout,
F. E. Turneaure,
F. P. Turner,
C. E. Webb,
H. T. Welty,
A. R. Wilson,
W. M. Wilson,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Specifications for fusion welding and gas cutting for steel structures, collaborating with ASTM Committee A–1 on Steel, and the American Welding Society Conference Committee on Bridges. Progress in study—no report.

3. Different grades of bronzes to be used for various purposes in connection with iron and steel structures (Appendix B). Complete, with recommended conclusion for publication in the Manual.

4. Design of expansion joints involving iron and steel structures. Progress in study—no report.

5. Design of tension members and connections in which rivets develop tension. Progress in study—no report.

6. Review specifications for overhead highway bridges of the American Association of State Highway Officials in so far as they relate to steel construction, conferring with that association. Progress in study—no report.

7. Progress in design of steel bridge details. Progress in study—no report.

The Committee on Iron and Steel Structures,
R. A. Van Ness, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

O. E. Selby, Chairman, Subcommittee; F. E. Bates, R. N. Brodie, O. F. Dalstrom, H. Ensz, W. G. Grove, C. S. Heritage, O. E. Hovey, A. R. Ketterson, A. M. Knowles, H. S. Loeffler, F. M. Masters, O. K. Peck, I. L. Simmons, S. M. Smith, H. C. Tammen, G. H. Trout, F. E. Turneaure, C. E. Webb.

Substitute for "Instructions for the Mill Inspection of Structural Steel" on page 15–115 of the Manual, new Instructions as follows:

Bulletin 408, January, 1939.

INSTRUCTIONS FOR THE MILL INSPECTION OF STRUCTURAL STEEL

1939

1. Study the contract and specifications and obtain such information about the proposed structure as will permit a full understanding of the uses to be made of the various items of the order.

2. Obtain copies of the purchase orders, specification references, shipping directions, and other information about the material to be inspected.

3. Study the operations of the mills and become familiar with the various processes of manufacture.

Cultivate the acquaintance of the mill employees and become familiar with their work, so as to have direct knowledge of the mill practice, and determine, as well as the circumstances permit, the correctness of the mill practice in so far as it is covered by the specifications.

4. When notified that material is awaiting inspection at the mill, arrange for prompt inspection and conduct the inspection and tests so as not to interfere unnecessarily with the operation of the mill.

5. When called for in the specifications, supervise the selection, stamping and preparation of test specimens; when not so called for in the specifications, check the identification of the test specimens as presented with the manufacturer's test sheet. This identification should be clear, legible, and free from apparent alterations.

6. Witness the making of tensile, bending, and other tests that may be required by the specifications. Observe that the testing machines are properly handled and that the specified speed of pulling is not exceeded. Note the behavior of the metal and check and record the results of the tests.

7. Obtain records of the chemical analyses of the melts from the manufacturer, and accept only those melts in which the specified contents of impurities are not exceeded.

8. Obtain pieces of the test ingots and test specimens, and have check analyses made outside of the manufacturer's laboratory if the analyses furnished by the manufacturer are erratic or for any other reason appear to be incorrect; provided this procedure is in accordance with the requirements of the specifications.

9. Record all tests and analyses on the form provided.

10. Verify the sections of materials by measurements or by weight, as provided in the specifications.

11. Report promptly the shipment of material from the mill when surface inspection has been waived, so that additional care may be exercised by the shop inspector during the fabrication.

12. Inspection of finished material should be so made as to insure, so far as possible, a product free from injurious defects, such as scabs, snakes, or laminations. The ultimate use of the material should be kept in mind and an effort made to judge it with a view to preventing shipment of material which may develop difficulties in fabrication or which may result in a faulty finished structure.

13. Keep informed as to the progress of the work in the fabricating shop and try to obtain the shipment of material at such time and in such order as to avoid delay in the fabrication.

14. Obtain copies of the shipping lists and compare them with the orders, making regular statements of the material that has been rolled and shipped.

15. Make reports weekly or as may be directed, submitting complete records of tests, analyses, and shipments, and such other information as may be required.

Substitute for "Instructions for the Inspection of the Fabrication of Steel Bridges" on pages 15–116 to 15–118 inclusive, new Instructions as follows:

INSTRUCTIONS FOR THE INSPECTION OF THE FABRICATION OF STEEL BRIDGES

1939

General

1. Study the contract, plans, and specifications in advance. Obtain such information as will permit a full understanding of the conditions, such as the time of delivery, the desired order of shipment, and any special features in connection with delivery.

2. When notified of the beginning of fabrication, arrange for prompt inspection. So conduct the inspection as not to interfere unnecessarily with the scheduled operations of the shop. Inspection should be made during the progress of the work and should keep up with the fabrication, in order that errors may be corrected before the work leaves the shop.

3. The sequence of inspection, so far as practicable, should be such as to permit the shop to ship in the correct sequence for erection.

4. Try to maintain pleasant relations with the foremen and workmen, and by fairness, decisiveness, and good sense, interest them in the successful completion of the work.

5. Require that all provisions in the plans and specifications be complied with. When unusual circumstances require changes in plans or specifications, report such changes promptly for a quick decision.

6. Allow to be used only such material as has been rolled for the work, and accepted, or other material which complies in all respects with the specifications.

7. Give careful attention to the condition of plain material, and to the quality of workmanship (such as accuracy in punching, assembling and alinement, and tightness of rivets) and to the finishing of machined parts, painting, and general finish.

8. Check every finished member against the drawings for its general dimensions and for the section of each piece of material forming a component part of the member.

9. Watch for bends, kinks, and twists in the finished members and make certain that when leaving the shop, members are in proper condition for erection.

10. On any work that requires welding, watch carefully to see that the requirements of the plans and specifications regarding qualifications of welders and quality of electrodes are complied with.

11. Ascertain in advance that the paint provided complies with the specifications. Watch carefully the painting directions to make sure that paint is properly applied and only where intended.

Details of Fabrication

12. Make sure that reamed holes are cylindrical and that shavings are not allowed to remain between assembled parts.

13. Make sure that shop splices are properly fitted and that the finished surfaces that are to take bearing are in close contact during the riveting.

14. Examine and measure pin holes carefully to insure proper position, size and spacing, and smoothness of finish.

15. Check the camber of plate girders and make sure that the camber is not reversed.

16. In trusses and girders assembled for reaming, make sure that the desired camber is secured before reaming. Obtain match-marking diagrams for such work, and make sure that the match marks are legible.

17. When a large number of pieces exactly alike are required, the number of pieces to be assembled for a check should be governed by the accuracy of workmanship. If errors are found, enough pieces should be assembled to make it reasonably certain that errors have been eliminated.

18. When sole plates on girders are beveled, check the plates before riveting to make sure that the bevels are not reversed.

19. When tight fit or driving fit bolts are used, make sure that the holes are reamed to templet or with the parts assembled.

20. Inspect castings carefully for blowholes and other imperfections, discriminating between such defects as are unimportant and such as would render the castings unfit for use. Slight imperfections that do not impair the strength of the castings may be corrected by welding.

21. Study the field connections to insure proper fit and ease of erection, paying particular attention to clearances, field rivet holes and fit of bevels.

22. When girders or beams are to be placed between colunms and erected in a row, measure the width of each column and the over-all length of each girder or beam to prevent their building out or exceeding the designed total length.

23. When clearance is provided for overrun in the depth of I-beams or for the "growth" of contiguous members, make sure that adjusting shims are provided.

24. Require that provision be made for the adjustment of handrailing both horizontally and vertically during erection.

25. Make sure that stringers connecting to floor beams below the top flange have enough clearance between the top of the stringer and the underside of the floor beam flange, for a possible overrun in the depth of the stringer.

26. Check ends of all members connecting to other members, for possible interference. This will include ends of bracing, cuts and copes on beam work, and similar connections.

27. Note the amount of space provided for driving field rivets and check the clearance for either bucking up or driving, as the case may be.

28. Check rights and lefts to be sure that the proper number of each is shipped.

29. Try enough countersunk head bolts in the holes where they are to be used to insure a proper fit. When rivets with countersunk heads are used to clear surfaces in contact, make sure that the heads are chipped flush with the surface.

30. Inspect the field rivets to see that they are free from fins or other defects. Make sure that drift pins of proper size, fitting up bolts and washers (when required) and the correct number and size of field rivets are provided.

31. When eye-bars are required, select the bars for full-size tests, witness such tests, and check and record the results.

Machine Shop Work

32. Exercise special care in the examination of moving parts and pieces in contact.

33. Study the details of machinery, discriminating between those dimensions which must be held to close tolerances and those in which greater variations are permissible.

Find out in advance the desired accuracy of fit for bolts, keys, and similar parts, and make sure that such accuracy is attained.

34. Make sure that expansion rollers, turntable rollers, and similar parts are accurate in size, properly assembled, and adjusted to distribute equally the loads which may be placed upon them.

35. Make sure that bushings, collars, and similar parts are held securely in place.

Shipments

36. Verify the shop marks and make sure that they are legible and correct.

37. When erecting conditions are such that important members cannot be turned end for end, see that such instructions are given on the bills of lading that those members will be headed in the right direction upon arrival at the site.

38. Make sure that rivets, tie rods, anchorage material, and miscellaneous parts are shipped in time to avoid delay in erection.

39. Make sure that small pieces are bolted in place for shipment if so shown on the plans, and that other small parts are properly boxed or otherwise protected against loss.

40. Whenever practicable, attend the weighing of material purchased on a scale weight basis. Make sure that the scales are accurate.

Reports

41. Observe carefully and report any unusual difficulties that may have been encountered in fabrication and the means adopted to overcome them. Try by a study of the details or other means to make recommendations that will prevent their recurrence in future work.

42. Make reports weekly or as directed, stating carefully and concisely the actual conditions.

Substitute for "Instructions for the Inspection of Bridge Erection" on pages 15–118 and 15–119, new Instructions as follows:

INSTRUCTIONS FOR THE INSPECTION OF BRIDGE ERECTION

1939

General

1. Provide yourself with:

(a) Special specifications applying to the work.
(b) Full set of design plans.
(c) Full set of final shop drawings and erection plans.
(d) Supply of report and record forms.
(e) Official train operating timetable.

2. Become fully acquainted with the terms of the contract, applicable general specifications (such as the current AREA Specifications for the Erection of Steel Railway Bridges), and method of procedure as approved or agreed upon.

3. Become familiar with local conditions affecting erection. Check the masonry as built with the steel plans before the work of placing the steel begins. If there is a resident engineer and staff, co-operate with them in making this check.

4. Obtain full information about the status of the work in the bridge shop and the probable dates of shipment.

5. Make sure that any necessary permits for the work have been obtained by the Railroad Company or the Contractor as the contract provides.

6. Study the scheme of erection and, to avoid delays, be prepared to suggest alternatives in an emergency.

7. Examine the erection equipment with a view to its safety and adequacy.

8. Keep informed about the contemplated use of work trains and assist in getting them when needed.

Traffic

9. Study the official train operating timetable and consult the proper operating officers about the time and relative importance of regular and extra trains. Become acquainted with any special traffic arrangements made because of the work in hand.

10. Before disturbing the track, make sure that arrangements have been made and have been approved by the division superintendent or other responsible operating officer. See that the necessary preparations are made so that the erection may proceed rapidly and with a minimum period of interference. Notify the proper authority as soon as the track is restored to service.

11. Keep constant watch over the detour or other temporary structure or falsework. Make such investigation as will disclose any evidence of failure or unsafe condition so that corrective action may be taken in time to prevent damage.

12. Have a definite method for checking speeds of trains and report violations of restrictions.

13. See that all trains are stopped when passing conditions are doubtful for any reason. Check the flag protection immediately before the beginning of any critical operation.

Materials

14. Keep a list of all material received, checking it against the shipping lists. Try to anticipate any shortage of material, using every available means to hasten delivery of the needed parts.

15. Obtain information regarding any incomplete or incorrect work that must be attended to after arrival at the site. If time permits, notify the fabricating contractor before making extensive corrections. Keep a record of time spent and materials used in this work.

16. Obtain a match-marking diagram of any existing structure that is to be removed and re-erected. Make a record of the manner of dismantling, of the nature and extent of damage to any part, and indicate by sketches or by description any repairs or replacements required when re-erected.

17. Be informed as to the use of Company material by the Contractor, and assist in getting it when necessary. Make sure that this material is not damaged unnecessarily.

Records and Reports

18. Keep a diary of the work. Make, on the prescribed forms, a daily report of the force employed and distribution of labor. Record the amount and kind of equipment use. Note the status of the work, the weather and working conditions, and record the names of official visitors. Make other reports if directed.

19. When extra or additional work is authorized, or is claimed by the Contractor:

(a) *Force account*

Check daily the Contractor's time sheets, payrolls, invoices for materials used, equipment rentals, and other items for which he may claim reimbursement. Keep your own record of the time of each class of labor and quantity of material used, noting any furnished by the Railroad Company.

(b) *Additional Units at Contract Price*

Keep a record of the number of units of each class of work completed by the Contractor.

20. Report errors or misfits in the work and keep a record of corrections made and of the cost if obtainable.

21. Keep a record of all flagging of trains, whether for the Contractor's benefit or otherwise, and of any delay to trains, noting the cause.

22. Make detailed reports of all accidents and personal injuries whether to persons employed on the work or others.

23. If so directed, make or obtain photographic records of progress and of important features of the work.

Progress and General Conduct of Work

24. Study the progress of the work periodically to ascertain if it is likely to be completed within the time allotted. If not, try to obtain enough additions to the force and equipment to attain this result.

25. In your dealings wih the Contractor's representative, be courteous but firm and definite concerning matters plainly within your authority, but adopt a suggestive, rather than a dictatorial, attitude whenever possible, especially as to items for which the Contractor is finally responsible.

26. Be constantly on hand when work is in progress and note any special difficulty in assembling.

27. Present to the Contractor at once for his attention any violation of the specifications or contract, and obtain a correction or else refer the matter to the proper authorities as soon as possible.

28. Call attention to any conditions of weather or other conditions, or to any practices, that may be dangerous to the workmen or that may result in delays to the work.

Details of Erection

29. Examine the match-marks and make sure that each member of the structure is placed in its proper position. Try to have members assembled in such order that no unsatisfactory makeshifts need be resorted to in getting some minor member into place.

30. Make sure that all parts of the structure are properly alined and that any required camber exists before permanent connections are made.

31. Prevent any abuse or rough handling of material. Bending, straining, overpinning, and heavy pounding with sledges are included in such abuse.

32. Check all temporary connections, and with particular care those affecting the safety of traffic, to make sure that the number of bolts and drift pins provided for, or agreed upon, have been used.

33. Watch the use of fillers, washers, and threaded members to see that they are neither omitted nor misused.

34. Watch the heating of rivets to prevent overheating or underheating and to make sure that scale is removed.

35. Test promptly and carefully all field-driven rivets and indicate loose or defective ones plainly, preferably with punch or chisel marks. Have these replaced before the scaffolding is removed, if possible. See that approved connections are painted as soon as practicable. Have any rivets replaced that may have been loosened in the course of erection.

36. Prevent damage to the surrounding metal and to the connection while removing rivets. Have the shanks drilled out if otherwise excessive force would be required for their removal.

37. Inspect with special attention the setting of bearing blocks or pedestals under shoes, also the setting of the shoes, to make sure that an even bearing is obtained. See that expansion bearings are set in the correct position to correspond with the temperature at the time.

Movable Bridges

38. Study the scheme of erection to see that it will not interfere with maintaining the clear channel required for navigation. See that the terms of the permit to close or obstruct the channel are complied with, and that the Contractor's operations do not delay the passage of watercraft during open periods. Keep a record of the circumstances and duration of any delays.

39. Prevent damage to machinery parts in unloading and storing, keep packings and wrappings intact, and keep sand, dirt, and grit from entering gears, bearings, trunnions, and wire ropes.

40. Determine whether electrical or other parts, protected in the finished structure, have been properly housed or otherwise protected from the weather when stored. Inspect the housing and storing of the counterweight ropes and operating ropes, and determine whether dressing coats have been applied at the allowable temperatures and with the proper time interval; prevent kinks, short bends, hauling through dirt, and other abuse of these ropes during erection.

41. Try to obtain an alinement in equal-arm swing spans such that either end will fit into the latches and other contacts when turned 180 degrees.

42. Inspect with special care the alining of trunnion and journal bearings. Inspect center bearings of swing spans to make sure that bearing surfaces are clean and properly lubricated.

43. Where wedges are driven by means of a crank arm and an adjustable link, see that the link and the arm form a straight line with the wedge fully driven.

44. Determine whether the navigation lights used during erection, or in the dismantling of old spans, meet government requirements.

45. Determine whether power line, cables, or other construction by the Railroad Company is likely to be completed in the time set for operating the bridge; also check the status of signal, interlocking or other material that may be furnished by the Railroad Company.

46. Check the weight of a cubic foot of the counterweight to determine whether it agrees with the weight used in the calculations. Check the location and number of adjusting blocks in the erected counterweight necessary to obtain a balance.

47. Check the filling of grease cups and the lubrication of wedges and other rubbing surface during erection, and particularly before the idling run of the operating machinery and the final acceptance test.

Welded Work

48. For instructions for the inspection of welded work refer to Section 9 of the current Specifications for Welded Highway and Railway Bridges of the American Welding Society, or such other welding specifications as may be finally approved by the AREA.

Cleaning Up Site

49. Supervise the removal of all falsework from the site, so that no obstructions to land or water traffic remain, making whatever investigation may be necessary to insure this, particularly as to underwater obstructions.

50. When the work has been completed, see that all surplus or discarded material is removed from the bridge and the vicinity, according to the terms of the contract or as instructed. Finally, see that the site is cleaned up and left in a neat and orderly condition.

Appendix B

(3) DIFFERENT GRADES OF BRONZES TO BE USED FOR VARIOUS PURPOSES IN CONNECTION WITH IRON AND STEEL STRUCTURES

R. P. Davis, Chairman, Subcommittee; J. Aston, J. E. Bernhardt, W. G. Grove, S. Hardesty, C. H. Mercer, O. E. Selby, C. S. Sheldon, H. C. Tammen, G. H. Tinker, F. P. Turner.

This subcommittee has collaborated with Committee B–5 of the American Society for Testing Materials on specifications for bronze bearing and expansion plates, to be used in connection with iron and steel structures. The American Society for Testing Materials has adopted such specifications tentatively and Committee 15 recommends that the following reference be authorized for printing in the Manual as an addition to the Specifications for Steel Railway Bridges.

XVII—BRONZES

1701. Cast bronze bearing and expansion plates shall conform to the tentative specifications of the American Society for Testing Materials, Designation B22–38T.

1702. Rolled bronze bearing and expansion plates shall conform to the tentative specifications of the American Society for Testing Materials, Designation B100–38T.

REPORT OF SPECIAL COMMITTEE—ECONOMICS OF BRIDGES AND TRESTLES

ARTHUR RIDGWAY, *Chairman;* A. C. IRWIN, F. J. PITCHER,
F. H. CRAMER, A. M. KNOWLES, L. W. SKOV,*
R. P. HART, H. S. LOEFFLER, T. H. STRATE,
Committee.

* Died November 16, 1938.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subject:

Comparative economic value of steel, treated timber, and concrete in bridges, trestles, and viaducts under various conditions of service, with due consideration of relative influence of durability of materials and obsolescence of property.

The committee has heretofore returned certain conclusions resulting from its study of the subject, and the discussion leading to them appears in the Proceedings for 1937, Vol. 38, page 433, to which attention is directed. Much of that discussion, supplemented by the results of further study, leads to the following two conclusions which the committee recommends be added in numerical order to those now appearing in the Manual:

4. The physical characteristics of the three kinds of material differ so widely that each has its field of economic usefulness to the exclusion of the others, and all are economically essential for the particular purposes for which they are peculiarly fitted.

5. The varied requirements of bridges, trestles, and viaducts are such that no precise and universally comparative values can be assigned to the economic employment of steel, concrete, and treated timber in such structures.

The committee also recommends there be incorporated in the Manual immediately after the title, "Comparative Value of Steel, Treated Timber and Concrete in Bridges", and immediately preceding the numbered conclusions, which the committee recommends be entitled "Conclusions" for purposes of differentiation, the following economic principles heretofore reported in the Proceedings for 1935, Vol. 36, page 115, and the Proceedings for 1937, Vol. 38, page 433, supplemented by the results of this year's study.

ECONOMIC PRINCIPLES

That which costs least may be extravagant, and the purchase of a high-priced article may be a provident transaction. It all depends on intrinsic value of that for which a price is paid or cost incurred. Economics is therefore a weighing of values, that is, a comparison of value received with price paid. The value received is not necessarily physical property, but may be, and often is, a need or a use. The matter of economics may be expressed mathematically thus:

$$\text{Economy} = (\text{Value}) - (\text{Price}).$$

From this it is clear that when intrinsic value, be it use, need, physical property, or whatnot, equals the price paid, the exchange is economical. If in another transaction it exceeds the price paid, the second is more economical than the first, and if in any exchange it exceeds by the greatest possible amount the price paid, it is the most economical. Conversely, if the price paid is more than the intrinsic value, economy is negative and the transaction is extravagant, the degree of extravagance depending on the excess of the price beyond the value.

Bulletin 408, January, 1939.

In the case of a bridge or other physical property not to be consumed, stored, or immediately used up, its value is to be found largely in its utility, and since its price is not a spot cash transaction but involves other expense, the economy equation may be written:

$$\text{Economy} = (\text{Utility}) - (\text{Cost}),$$

in which "Utility" is a group of three values consisting of the utility of the project, the security of its readiness to serve its purpose, and the appearance of esthetic value of the complete structure.

Structural Values

Utility has to do primarily with the purpose of the structure and the bare essentials of work it must perform which, in case of a bridge, trestle, or viaduct, consist of carrying a particular rail traffic over a particular waterway or other traffic. Use requirements are therefore very definite and peculiar to one site only.

Security as here used means the assurance with which a structure at all times performs its functions with safety to life and property possessed by or in the custody of the owner and also its structural immunity from functional impairment by natural or other casualties. Perfect assurance also includes an element of reliability in meeting occasional extraordinary service demands in emergency. Protection against physical loss only can be obtained by monetary outlay for insurance and hence dependable service must be safeguarded by design.

Without doubt in all privately managed industry there runs a thread of duty to aid in the cultural development of society at large. This is especially pronounced in an essentially public service industry conducted in a democracy where there is no recognized rank among the members thereof. Any system of economics that does not incorporate some idea of social advancement is incomplete, the amount of consideration warranted being dependent upon the local conditions both social and industrial. There are no rules extant for guidance, and the designer of an engineering project must be governed by the few known principles pertinent to its appearance to casual observers. These must be of course very general and leave to the individual the discretionary privilege of weighing their relative importance.

These three factors embrace all service requirements and their values are automatically provided for in the cost of any structure designed to satisfy them.

Fiscal and Engineering Costs

The design and hence initial cost of a structure is governed by use requirements, and if these requirements cannot be fully satisfied regardless of initial cost, then that design is eliminated from any comparison sought and the problem is thus simplified at the outset. Obviously, the first cost of any one type will vary also with different owners or even with different locations on an individual owner's property, depending upon prices paid for labor and material co-ordinated with the particular conditions surrounding the site or installation and customary working methods.

Two governing factors in the liquidation of original investment or funding replacement cost at the end of the user period are cost of replacement itself and length of serviceable life. An accurate forecast of the replacement cost of a long-lived structure is at once a matter of speculation and probably the best that can be done about it is to assume replacement and installation costs will be equal. Such disposition leaves only the other factor for consideration—length of serviceable life.

The most important element influencing the length of serviceable life of any structure is the durability of the material of which it is constructed, and next in order of importance, grouped under the category of obsolescence, may be listed: Change in location or changes in the structure itself, change in the character of use for which the structure was designed, substitution of more suitable structural material or more economical design, and cessation of the need for any structure at all. It is very evident that not only is the length of serviceable life a prime factor in annual cost, but it is also most illusive of precise determination and clearly must be the result of individual analysis of present conditions and probable future developments.

In addition to the interest on the investment cost of a long-lived structure and sinking fund increments to aggregate cost of replacement at the end of its serviceable life or to liquidate the original investment in case the structure is not to be replaced, there are several other elements of cost which must be included to obtain the whole cost. These may be grouped into three classes—maintenance costs, insurance premiums, and tax levies.

Maintenance costs are direct and include all sums expended for inspection, repairs, and protection of the structure against deterioration by the elements.

Insurance expense, whether for fire, flood, or other coverage, is a proper item of cost of utilization, and if not in the form of actual premiums paid, an appraisal of the assumed risk should be used in lieu thereof. It is of course not possible generally to insure against other than property damage, and to attempt an appraisal in monetary terms of all hazards to dependable service would be futile.

Railroad taxes, regardless of the method of assessment, must necessarily bear some relation to the cost or value of the fixed physical property, and though it is difficult in most cases to allocate a proper proportion of assessment to a particular structure, such an item should be included in the whole cost even if it is only a well-considered estimate.

Unique Properties of Materials

The physical characteristics and availability of the three structural materials under consideration indicate the purpose for which each is best fitted and the practical limitations in its use.

Timber as compared with steel is greatly deficient in all strength elements but excels concrete in tensile and flexural strength. Notwithstanding its strength deficiencies and combustible nature, timber is indispensable for those structures in which future conditions of service or permanency of location are uncertain. The ease and convenience of piecemeal renewal and superior adaptability in change to other types render the use of timber imperative in some circumstances.

Concrete, a characteristically granular material, is relatively low in tensile strength, but due to its hardness and density, has far greater compressive and bearing strength than timber and when compositely reinforced with steel at once becomes a structural material of general utility. The durability of concrete in large masses and the availability of materials therefor are such that where great inertia and stability are required its use for such purposes is of prime necessity.

In all strength characteristics steel so greatly excels timber and concrete and is so readily adaptable for all uses above substructure and foundation that it is absolutely requisite for certain classes of structures such as long spans and high viaduct.

There is no basis for determining the comparative economy of things essential and where there is a choice, a comparison of economic value of materials can only be determined by engineering analyses.

Special Committee on Economics of Bridges and Trestles,
Arthur Ridgway, *Chairman.*

REPORT OF COMMITTEE 7—WOOD BRIDGES AND TRESTLES

H. M. Church, *Chairman;*
H. Austill,
M. W. Beach,
Walter J. Bennett,
G. M. Cornell,
F. H. Cramer,
G. S. Crites,
S. F. Grear,
W. E. Hawley,
H. C. Heinlen,
C. J. Hogue,
C. S. Johnson,
J. V. Johnston,
W. D. Keeney,
J. E. Myer,
John A. Newlin,
W. H. O'Brien,
W. A. Oliver,
W. L. Peoples,
R. P. Hart, *Vice-Chairman;*
G. W. Rear,
Arthur Ridgway,
W. R. Roof,
W. J. Ryan,
Walter C. Schakel,
L. W. Smith,
G. L. Staley,
T. G. Sughrue,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Simplification of grading rules and classification of timber for railway uses, collaborating with other organizations interested. A proposed revision of American Lumber Standards was reviewed and suggestions for its improvement submitted to the National Bureau of Standards.

3. Overhead wood or combination wood and metal highway bridges, collaborating with Committee 15—Iron and Steel Structures (Appendix B). Progress report.

4. Design of wood trestles for heavy loadings. Progress in study—no report.

5. Bearing power of wood piles, with recommendations as to methods of determination, collaborating with Committee 8—Masonry. Progress in study—no report.

6. Recommended relationships between the energy of hammer and the weight or mass of pile for proper pile driving, to include concrete piles, collaborating with Committee 8—Masonry (Appendix C). Progress report, including Specifications for Driving Wood Piles, submitted as information.

7. Improved design of wood structures to give longer life with lower cost of maintenance. Progress in study—no report.

8. Review specifications for overhead highway bridges of the American Association of State Highway Officials in so far as they relate to wood construction, conferring with that association and Committee 15—Iron and Steel Structures (Appendix D). Progress report.

9. Fireproofing wood bridges and trestles, including placing of fire stops (Appendix E). Progress report.

10. Specifications and design of fastenings for timber structures, including metal joint connectors. Progress in study—no report.

11. Use of tar and asphalt compositions for wearing surfaces on wood floored highway bridges (Appendix F). Progress report.

The Committee on Wood Bridges and Trestles,
H. M. Church, *Chairman.*

Bulletin 408, January, 1939.

Appendix A

(1) REVISION OF MANUAL

R. P. Hart, Chairman, Subcommittee; Arthur Ridgway, J. V. Johnston, W. E. Hawley.

The following revisions in the Manual are recommended:

For the sake of uniformity, substitute the word "piles" for "piling" where it appears in

line 1, paragraph 101, page 7–1
line 2, paragraph 201, page 7–1
line 4, paragraph 205, page 7–2

Correct the table of dimensions of cedar piles for highway bridges under paragraph 301, page 7–3, to conform to dimensions adopted by the American Society for Testing Materials as originally agreed upon by the committee:

As it now appears—

Under 30 feet	13 inches	22 inches	8 inches
30 feet to 40 feet incl.	13 inches	22 inches	8 inches
Over 40 feet	13 inches	22 inches	7 inches

As proposed—

Under 30 feet	12 inches	22 inches	8 inches
30 feet to 40 feet incl.	13 inches	22 inches	8 inches
Over 40 feet	13 inches	22 inches	7 inches

Appendix B

(3) OVERHEAD WOOD OR COMBINATION WOOD AND METAL HIGHWAY BRIDGES

G. L. Staley, Chairman, Subcommittee; F. H. Cramer, H. C. Heinlen, C. J. Hogue, W. H. O'Brien, W. A. Oliver, G. W. Rear.

The record of work of this subcommittee for the past ten years has been reviewed, and this record has been discussed and considered as to the current aspects of the subject, bearing in mind the rapid progress made in highway construction during this time and the assumption of maintenance of both new and old highway bridges over railroad tracks by the states and other governmental units. The committee feels that the proposed report, if it should become the action of the association, will serve to further this very desirable practice.

The committee feels that this subject is a matter that must be determined by the desires and requirements of highway users. Therefore, any structure carrying highway traffic, whether on a public or private road, should be designed, constructed and maintained in accordance with the standards and practices of the state in which the bridge is located. The subject should properly include all highway bridges of timber, whether "overhead", as the assignment states, or otherwise. The following is therefore the conclusion of the committee and is recommended for adoption in the Manual as recommended standard practice.

Specifications for Wood Highway Bridges

It is recommended that the Standard Specifications for Highway Bridges of the American Association of State Highway Officials adopted in 1935, or current revisions

thereof, be used, subject to the approval of the railway company as to clearances, foundations and construction practices.

It is recommended that the subject be continued.

Appendix C

(6) RECOMMENDED RELATIONSHIPS BETWEEN THE ENERGY OF HAMMER AND THE WEIGHT OR MASS OF PILE FOR PROPER DRIVING, TO INCLUDE CONCRETE PILES*

H. C. Heinlen, Chairman, Subcommittee; G. S. Crites, R. P. Hart, W. D. Keeney, W. L. Peoples, W. J. Ryan, T. G. Sughrue.

In determining the weight or size and capacity of the hammer to be used for any service, due consideration must be given to the weight and spacing of the piles, the character and condition of the soil to be penetrated, conditions of driving, and former experience at the site or under similar conditions. The blow should be struck by a ram having sufficient energy to overcome the inertia of the pile and the frictional and elastic resistance encountered, and having sufficient weight to reduce to a minimum the portion of this energy which is unavoidably dissipated in destructive work during impact. As a general rule, piles should be driven with the heaviest hammer that, in the judgment of the Engineer, can be used to secure maximum penetration without appreciable damage to the pile.

Steam Hammers

For driving concrete piles, the hammer shall have sufficient weight and power to develop an energy per blow, at each full stroke of the piston, of not less than 3,500 foot-pounds per cubic yard of concrete contained in the pile to be driven. The total energy developed by the hammer shall be not less than 12,000 foot-pounds per blow.

For driving wood piles, the weight of the striking part of the hammer should be not less than the weight of the pile to be driven.

In general, the minimum weight of the entire hammer and of the striking part, and the length of stroke should, where practicable, be specified for each project. Where hard driving is encountered, it may be necessary to reduce the length of stroke in order to avoid injury to the pile.

Gravity Hammers

For driving either concrete or wood piles, the weight of the striking ram shall be not less than 3,000 pounds and the drop shall be so regulated as to obtain the desired penetration without appreciable injury to the pile.

This is a progress report, presented as information. The committee also presents the following Specifications for Driving Wood Piles for study and criticism pending their submission for adoption and publication in the Manual.

* Opinions, mathematical demonstrations and graphical data supporting the recommendations appearing in this report were published in the Proceedings for 1936, Vol. 37, pp. 706–716.

SPECIFICATIONS FOR DRIVING WOOD PILES

1. Scope

These specifications cover the driving of wood piles in trestles, foundations, and for protection work. For the driving of concrete piles and steel piles, see the "Masonry" chapter.

2. Tests

A thorough exploration shall be made at the proposed site by borings or preliminary test piles as indicated in the "Design of Pile Trestles" in this chapter and in the "Specifications for Pile Foundations" in the "Masonry" chapter.

3. Materials

The kinds of wood, physical requirements, dimensions, and manufacture are specified in this chapter.

4. Handling of Material

Treated piles shall be handled with rope slings, taking care to avoid dropping, bruising or breaking of outer fibers, or penetrating the surface with tools. Sharp pointed tools shall not be used in handling treated piles or turning them in the leads.

The surface of treated piles below cut-off elevation shall not be disturbed by boring holes or driving nails or spikes into them to support temporary material or staging. Staging may be supported in rope slings carried over the tops of piles or attached to pile clamps of an approved design.

5. Selection and Preparation of Piles

(a) Size

The piles in each bent of a pile trestle shall be selected for uniformity of size to facilitate placing of the brace timbers.

(b) Pointing

Piles may be pointed where soil conditions make it desirable.

(c) Pile Shoes

Where the driving of a test pile or former experience at the site indicates that difficult driving will be encountered, metal shoes of an approved design may be attached to the tips of the piles.

(d) Collars

Where the heads of the piles tend to check or split under the hammer, the heads shall be wrapped with wire, or metal bands applied to obviate this condition.

(e) Driving Cap

The heads of all piles shall be protected, while being driven, with a cushion cap of approved design. Care shall be exercised to insure full bearing of the driving cap on the pile for proper distribution of the hammer blow.

6. Types of Hammers

Pile driving shall not be started on any project until approval is secured from the Engineer as to the type and weight of the hammer to be used.

Piles shall be driven with the heaviest hammer that, in the judgment of the Engineer, can be used to secure maximum penetration without appreciable damage to the pile.

Where a drop hammer is used, the striking ram shall weigh not less than 3,000 pounds. The fall shall be so regulated as to avoid injury to the pile.

A steam hammer shall be used where the shock to surrounding material may cause damage to an adjacent structure.

7. Driving

(a) Leads

Pile driver leads shall be constructed in such a manner as to afford freedom of movement of the hammer, and they shall be held in position by guys or stiff braces to insure support for the pile during driving.

(b) Followers

The use of followers shall be avoided if practicable and shall be used only with the written permission of the Engineer.

(c) Line

Piles shall be driven as accurately as possible in the correct location, true to line both laterally and longitudinally, and to the vertical or batter lines as indicated on the plans. On sloping ground or under difficult conditions of driving, the pile shall be started in a hole or guiding templet or other necessary means provided to insure driving in the proper location. In case a pile works out of line in driving, it shall be properly alined before it is cut off or braced, and the distance that it may be pulled shall be determined by the Engineer.

(d) Jetting

When water jets are used, the number of jets and the volume and pressure of water shall be sufficient to freely erode the material adjacent to the pile. The plant shall have sufficient capacity to deliver at least 100 pounds per square inch pressure at two ¾-inch nozzles. Before the desired penetration is reached, the jets shall be removed and the pile finally set under normal driving by at least 50 blows from a gravity or single-acting steam hammer or 200 blows from a double-acting steam hammer.

(e) Drilling

When it has been satisfactorily demonstrated to the Engineer that piling cannot be driven in the regular manner or by jetting, holes may be drilled to facilitate the driving.

Where drilling is permitted, the holes drilled shall have a diameter not more than one inch larger than the tip diameter of the pile and the drilling will continue only through the strata of hard material obstructing the driving. Where the hard material extends below the desired penetration, the drilling shall be stopped above that penetration level and the pile finally set under normal driving by at least 50 blows from a gravity or single-acting steam hammer or 200 blows from a double-acting steam hammer.

(f) Drilling and Shooting

Where it is impossible to drive, jet, or drill and drive the piles, the Engineer will determine whether shooting the holes with explosives or redesign of the structure is necessary. Shooting will not be permitted except by written permission of the Engineer.

(g) Penetration

It is expected that piles shall be driven, jetted, or drilled and driven to the full penetration shown on the plans or as otherwise required. This shall not be construed to mean that driving may stop when such penetration as shown on the plans has been secured, but on the contrary, driving shall continue in every case until the total penetration obtained is satisfactory to the Engineer, regardless of the fact that sufficient bearing capacity as determined by formula may be obtained at a lesser depth.

(h) Bearing Capacity

Where possible, test piles shall be driven and loading tests made before construction is started. However, if these test data are not available, the following "Engineering News" formulas may be used to determine the approximate bearing capacity of piles:

For drop hammers $P = \frac{FWh}{S+1}$.

For single-acting steam hammers $P = \frac{FWh}{S+0.1}$.

For double-acting steam hammers $P = \frac{Fh\,(W + ap)}{S + 0.1}$.

Where P = safe load in pounds.
W = weight of hammer or ram in pounds.
h = fall of hammer or stroke of piston in feet.
S = average penetration in inches per blow, for the last 5 blows of a drop hammer or 20 blows of a steam hammer.
a = effective area of piston in square inches.
p = mean effective steam pressure in pounds per square inch.
F = 2 for piles driven to practical refusal in any material.

These formulas are applicable only when the hammer has a free fall, the head of the pile is not broomed or crushed, the penetration is reasonably uniform, and there is no appreciable bounce of the hammer. The character of the soil penetrated; conditions of driving; spacing, size and length of piles; and experience under similar conditions; shall be given due consideration in determining the value of piles by formula.

For jetted piles, the same formulas will apply and the test shall be made when driving is resumed after removal of the jets. For piles driven in drilled holes, the tests shall be made after the tip of the pile has passed the bottom of the hole.

(i) Delay

When driving is interrupted before final penetration is reached, record for bearing capacity shall not be taken until at least 12 inches penetration or refusal has been obtained after driving has been resumed.

(j) Overdriving

When the point of refusal is reached, care shall be taken to avoid damaging the pile by overdriving. This condition is indicated when the hammer begins to bounce, or when the energy of the blow is dissipated in the bending or kicking of the pile.

(k) Splicing

Full-length piles shall always be used where practicable, but when it is necessary to drive piles below cut-off elevation in order to secure satisfactory penetration, an approved method of splicing may be used. Piles shall not be spliced except by written permission of the Engineer.

(l) Replacing

Any pile driven too far out of line, or so injured in driving or straightening as to impair its structural value as a pile under the conditions of use, shall be pulled and replaced by a new pile.

8. Framing

(a) Cut-off

The tops of piles shall be pulled into line if necessary, fixed in position, cut off to a true plane as shown on the plans, and at the elevation established by the Engineer. Piles shall show a solid head at the plane of the cut-off.

(b) Treatment

After the cut-off has been made, the tops of treated piles shall be treated with a liberal quantity of hot preservative followed by two coats of hot sealing compound. For description of kinds of preservative and methods of application, see the "Wood Preservation" chapter.

(c) Pile Covering

Where the plans call for a heavy roofing material or galvanized metal pile covering, it shall be placed on the tops of the piles immediately after treatment, the edges bent down over the sides of the pile, neatly trimmed, and fastened with roofing nails.

(d) Placing Caps

Caps shall be placed while the piles are held in correct position. Where drift bolts are used for making the connection, the caps and tops of piles shall be bored the same diameter as the drift bolt and to a depth of 3 inches less than its length. Where the connection is made with straps and bolts, see paragraph *(f)* for boring and treatment of holes.

(e) Bracing

Piling shall not be trimmed or cut to facilitate the framing of sway or longitudinal bracing. Where necessary, filler blocks shall be used between the pile and brace to establish the bracing in a true plane.

(f) Holes for Bolts

Holes shall be bored the same diameter as the bolt.

When holes are bored in treated piles, caps or bracing in the field, the entire hole shall be pressure treated or swabbed with hot preservative and sealing compound just before the bolt is placed. Bolts shall be cleaned of rust and scale, and dipped in hot sealing compound before placing. All unused holes shall be plugged at each end with tight fitting treated wooden plugs.

(g) General Field Treatment

Where it is necessary to disturb the surface of treated piles or wood, or where the surface has been damaged in handling, such surfaces shall be treated with a liberal quantity of hot preservative followed by two applications of hot sealing compound.

9. Foundation Piles

For the design of pile foundations, exploration at the site, and test pile loading, see the "Masonry" chapter.

The general specifications above shall apply to the driving of wood foundation piles.

Pile driving shall not be started until foundation excavation has been carried to plan depth.

After all of the piles are driven, tests shall be made to determine if any of the piles have raised due to driving of adjacent piles. Any piles that have raised shall be driven down again.

After driving is completed, the piles shall be cut off as shown on the plans and at the elevation established by the Engineer. All loose and displaced materials down to the level of original excavation shall be removed from the foundation pit, leaving a clean solid surface on the piles, and bottom and walls of the pit.

10. Protection Work

The general specifications above shall apply to the driving of wood piles for protection work.

It is essential that protection work be constructed as securely as possible, accurately located as shown on the plans, and the piles driven to a fixed penetration or to refusal as may be determined by the Engineer.

These specifications are submitted as information with the object of presenting them later for adoption and publication in the Manual.

Appendix D

(8) REVIEW SPECIFICATIONS FOR OVERHEAD HIGHWAY BRIDGES OF THE AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS

In so Far as They Relate to Wood Construction, Conferring with that Association

S. F. Grear, Chairman, Subcommittee; G. S. Crites, W. E. Hawley, C. J. Hogue, W. H. O'Brien.

The committee has thoroughly reviewed the specifications of the American Association of State Highway Officials, printed in 1935. The portions relating to wood construction are such as to result in a satisfactory highway bridge.

The report is offered as information, with the recommendation that the subject be discontinued.

Appendix E

(9) FIREPROOFING WOOD BRIDGES AND TRESTLES, INCLUDING PLACING OF FIRE BARRIERS

J. V. Johnston, Chairman, Subcommittee; M. W. Beach, R. P. Hart, C. S. Johnson, G. L. Staley, T. G. Sughrue.

This committee was last assigned the subject of fireproofing in 1921, and in 1922 it offered and recommended to the Association for adoption the material on this subject which appears in the Manual on page 7–66.

The subject was revived on the floor of the 1937 convention, and assigned for further study. The importance of fire prevention is well recognized, for we know that so long as trestles are constructed of wood, an inflammable material, a fire hazard will always exist.

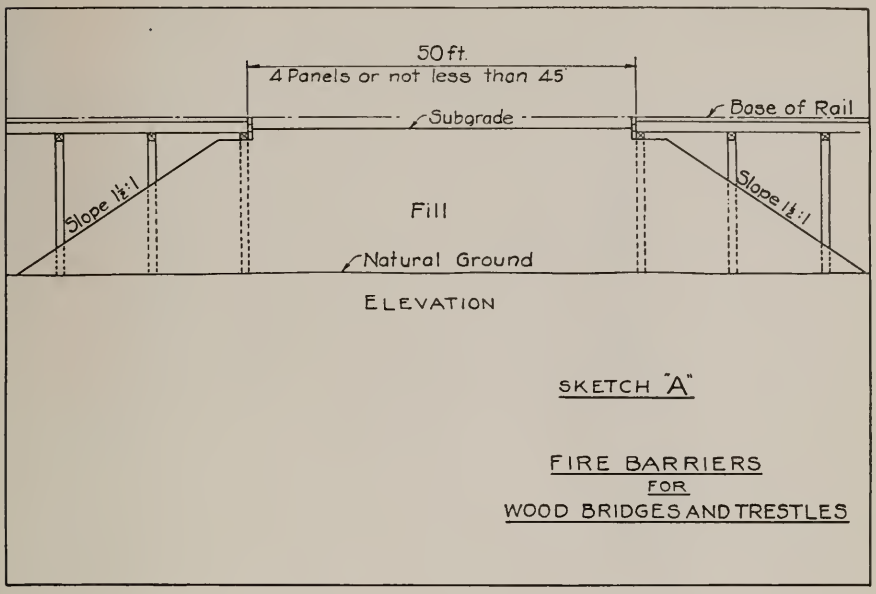
Your committee has reviewed the literature and reports pertaining to the protection of timber structures, and studied the reports of the Subcommittee on Fireproofing and Preservative Treatments of the National Fire Protection Association.

The general consensus as cited may be summarized as follows:

1. Application of normal methods of fire protection is believed to constitute adequate protection against fires.

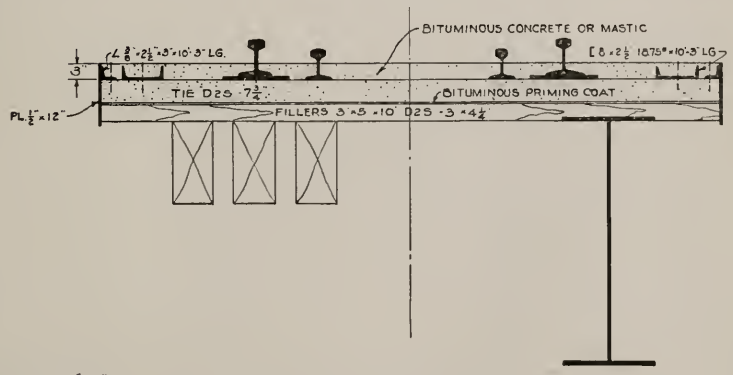
2. Common sense methods to guard against ignition of outdoor structures correspond to general practice and methods now contained in the Manual.

3. Failure to install fire barriers properly in docks and bridges is noted as a frequent cause of failure to confine fires to parts of the structure. Attention is called to paragraph 6, page 7–66, in the Manual.



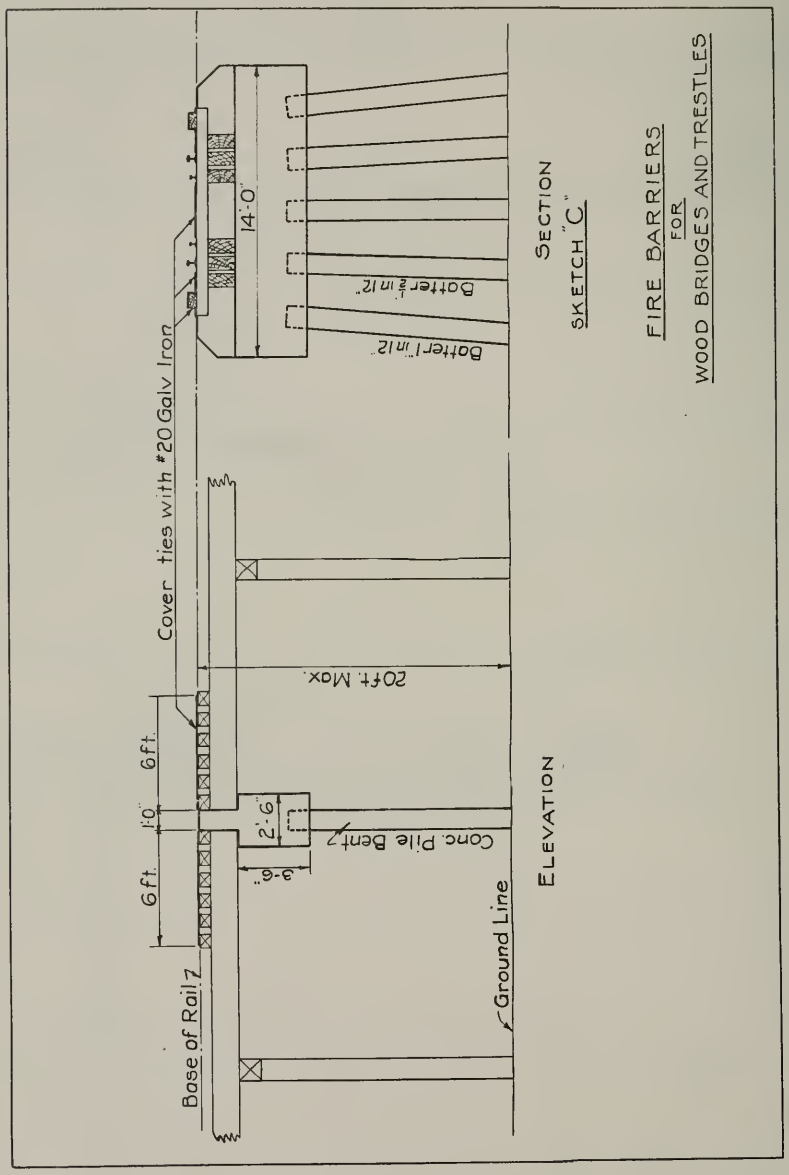
SKETCH "A"

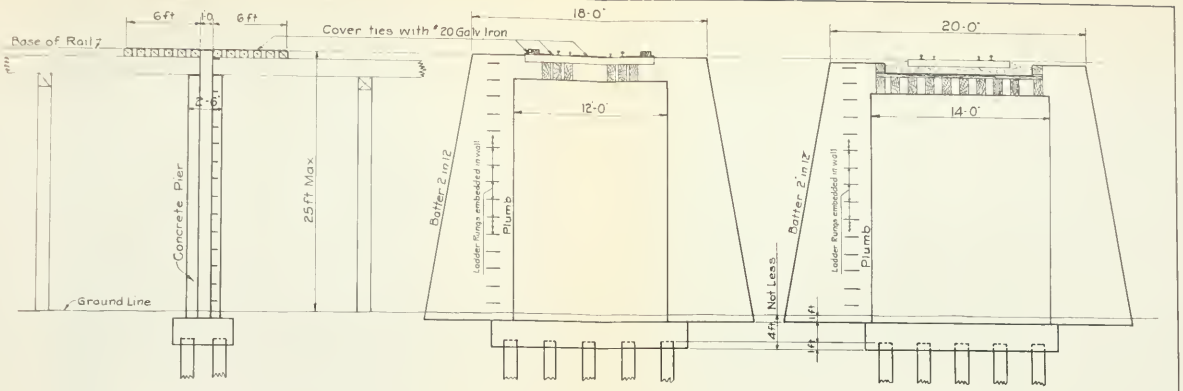
FIRE BARRIERS
FOR
WOOD BRIDGES AND TRESTLES



SKETCH "D"

FIRE BARRIERS
FOR
WOOD BRIDGES AND TRESTLES


FIRE BARRIERS
FOR
WOOD BRIDGES AND TRESTLES
SECTION
SKETCH "C"
ELEVATION
Cover ties with #20 Galv Iron
Batter 1" in 12"
Batter 1" in 12"
14'-0"
20ft. Max.
Conc. Pile Bent
2'-6"
3'-6"
6ft.
1'0"
6ft.
Base of Rail
Ground Line



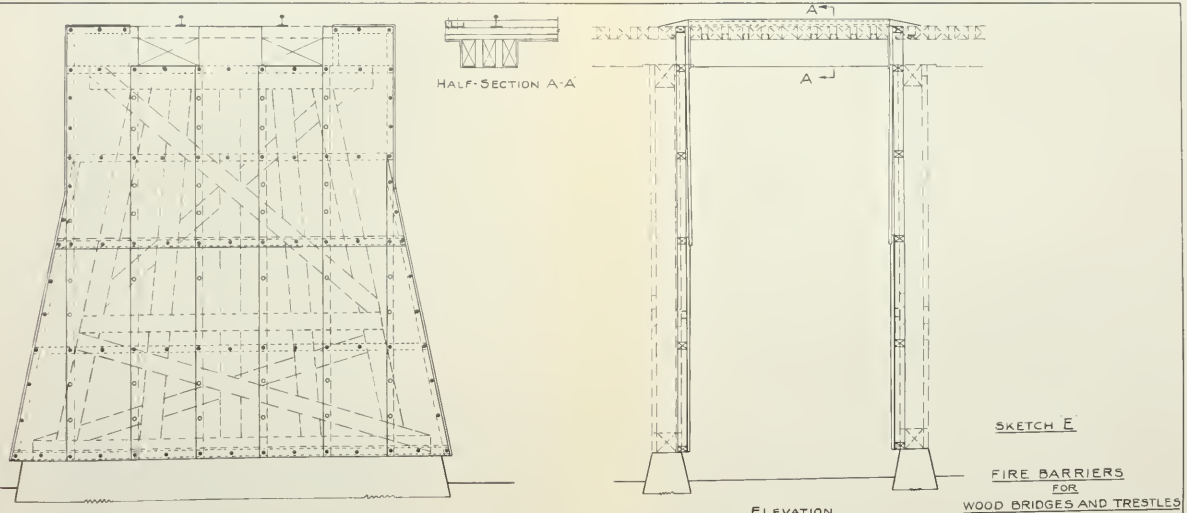
ELEVATION
Open Deck
Ballasted Deck Similar

SECTION
Open Deck

SECTION
Ballasted Deck

SKETCH B.

FIRE BARRIERS
FOR
WOOD BRIDGES AND TRESTLES



SECTION

ELEVATION

WOOD BENTS COVERED WITH FIRE RESISTANT MATERIAL

SKETCH E.

FIRE BARRIERS
FOR
WOOD BRIDGES AND TRESTLES

It is recommended that the study of this subject be continued, and it is hoped that this preliminary report will invite general attention so that the committee may receive suggestions from the entire membership as to improved methods and designs in use for the protection of outdoor wood structures. The future work of the National Fire Protection Association will also be given consideration.

Your committee in the study of fire barriers that may be used finds that they may be grouped into types of construction for open deck and ballasted deck wood trestles and highway bridges, as follows:

1. Earth fill within long trestles.
2. Reinforced concrete piers or concrete pile bents.
3. Fire resistant deck.
4. Facing bents with fire resisting materials.

The application of these methods is shown in sketches "A", "B", "C", "D", and "E", which are presented to invite discussion and suggestions for further study.

This report is offered as information, with the recommendation that the subject be continued.

Appendix F

(11) USE OF TAR AND ASPHALT COMPOSITIONS FOR WEARING SURFACES ON WOOD FLOORED HIGHWAY BRIDGES

G. S. Crites, Chairman, Subcommittee; W. D. Keeney, J. V. Johnston, W. C. Schakel, T. G. Sughrue.

General Requirements

Wood subfloor shall be securely fastened to prevent vibration and, unless otherwise specified, all sharp corners, projections or irregularities in surface shall be removed. Wood which is worn or containing defects injurious to the bituminous surface, shall be removed and replaced with new material. Any openings in the floor shall be completely sealed by caulking with oakum, or by other suitable means. All dust, dirt, debris, or foreign material on the surface to be treated shall be removed by sweeping with stiff brooms and if necessary the surface may be flushed with water. If water is used, the subfloor shall be allowed to become thoroughly dry and then swept with stiff brooms before applying the first coat.

Wherever possible, treated timber only should be used, as the extra life is well worth the costs. When freshly treated timber is used, the plank floor should be allowed to dry out prior to surfacing operations, to prevent softening of the surface coat. As a general precaution, when creosoted timber is used, the priming of the surface with tar or asphalt should be eliminated or reduced in amount to where it will be properly absorbed and not result in cutting back the prime to a lower viscosity. On dry or old creosoted timber, the prime should be reduced to about 0.15 gallon per square yard, depending on the amount of creosote treatment coming to the surface of the planks.

Single Plank Floors

There are still in use a great many wooden highway bridges having single plank floors, and they are difficult and costly to maintain. Most of these old bridges originally had wooden stringers, to which were nailed 3 inch wooden plank in transverse fashion. As the stringers rotted, new ones were placed, sometimes without removal of the old, so conditions progressively grew worse and occasionally a truck would break through the floor between cross beams. By reconstructing the stringers so as to distribute concen-

trated loading to the floor beams, and by placing a light wood flooring surfaced with tar or asphalt over them, many such old bridges can be made safe and useful for a long time to come, particularly on light traffic highways.

Single-plank floors work under concentrated loading and are difficult to keep completely sealed. On single planks, cotton fabric is an excellent material to use to prevent the floor cracks from progressing through the bituminous wearing course. No effort should be made to place a thick wearing surface on single-plank floors as the movement of the planks will break up a thick bituminous coating quickly. Rather, a thin, pliable but strongly adhesive coating should be placed, covered with fine aggregate, preferably sharp sand, approved screenings or finely crushed slag.

Double Plank Floors

The top planks should be at a right angle, or nearly as possible at a right angle to the bottom planks to prevent progressive cracks. The first treatment should consist of as much hot, cut-back or emulsified prime as the floor will absorb without running off. This usually amounts to about 0.5 gallon per square yard; but should be reduced to about 0.25 gallon, or less, per square yard where creosoted timber is used. There should be enough prime, however, to penetrate well through the upper layer of plank, spread over the lower layer and thereby waterproof the joint between. After the absorption of the prime coat a seal of hot, cut-back or emulsified bitumen should be applied at the rate of from 0.1 to 0.2 gallon per square yard, and covered with fine aggregate. Until the aggregate is in proper position, the surface should be lightly broomed; but the final mat should not exceed 0.25 inch thickness.

Vertical Laminated Floors

Two by fours, two by sixes, three by sixes, or even larger sizes of planks are sometimes placed with the greater dimension vertical. If desired, the larger planks can be preshaped so that a crown will be obtained. Each succeeding piece is nailed to the one previously laid with staggered joints until a continuous floor is completed. Locations guide as to whether planks are to be surfaced, partly surfaced or unsurfaced. Unplaned planks have a slightly uneven surface which gives a good anchorage for surface treatment. For such surfaces, bituminous surface treatment as prescribed for double-plank floors may be used. It is possible to increase the mat thickness and apply coarser aggregates if desired. Such floors should be seal-coated before they are put regularly into use; otherwise water will soak into the vertical joints, be retained there and cause swelling.

Grooved Laminated Floors

By alternating the depth of planks in vertical laminated floors, as by using 5-inch and 6-inch or 7-inch and 8-inch planks alternatingly for lamination, a grooved or cogged floor will result. This type of floor will give a mechanical bond between the planks and the bituminous wearing surface.

Saw-Tooth Laminated Floors

If floor planks of the same depth are milled with a 90-degree ridge uppermost and a laminated floor of saw-tooth effect built with them, a bituminous wearing surface can be applied without its becoming corrugated. Also, there is little liability of the wearing coat creeping or shearing, as the area of the entire surface would have to shear in order to slip on the planks. A floor of such construction allows for a suitable depth of bituminous coat under all conditions.

While laminated floors are somewhat thicker than single plank, they are infinitely stronger, more silent and will give service life much longer than that of flat planks. Also, they are more adaptable to the application of bituminous wearing surfaces.

I

Construction of Tar Mat Surface

Prime Coat—After the subfloor has been prepared as hereinbefore specified and is thoroughly dry, the entire surface shall be covered with a first coat of tar. The tar shall be applied cold at the rate of ¼ gallon per square yard where the plank floor is untreated; but when treated timber is used, the priming coat may be eliminated or reduced to avoid cutting the tar back to a lower viscosity. No traffic shall be permitted to use the surface thus treated. The prime coat shall remain in place 12 hours or more, until it is dry, before applying second application of tar.

Second Coat—The tar shall be heated in an open tank or kettle to a temperature between 150 degrees and 225 degrees F. and applied evenly to the surface at the rate of ½ gallon per square yard. The methods and appliances used shall be such as to insure a uniform distribution of the tar over the surface of the roadway. A suitable pressure spraying device, preferably, shall be employed. Immediately after the tar is sprayed or otherwise deposited upon the roadway surface, it shall be smoothed out to a uniform thickness by means of squeegees, mops or other suitable spreading device. Care shall be taken not to overheat the material, the proper temperature being obtained when it will flow with reasonable freedom and remain fluid for a sufficient period to permit the aggregate to become thoroughly incorporated in the mass.

Immediately after the application of this coat of tar the surface shall be covered with the aggregate at the rate of approximately 0.5 cubic foot per square yard. Accurate measuring or weighing devices shall be provided to insure the proper quantity of aggregate being used. The aggregate shall be spread evenly over the surface by means of square pointed shovels. As soon thereafter as practicable the surface shall be hand tamped or rolled with a heavy hand roller.

After rolling or tamping is completed, if successive applications of the tar and aggregates are necessary to obtain the required thickness they shall be applied in the same proportions and in the same manner as specified for the first application. The entire surface shall then be rolled or hand tamped as specified above.

Care shall be exercised to secure a smooth, even surface, free from depressions or irregularities, which when tested with a 10 foot straight-edge shall not vary by more than ¼ inch from the specified surface contour.

The total thickness of the tar mat shall be as specified but in no case shall exceed ¾ inch.

Construction of Asphalt Mat Surface (Mixed Method)

Prime Coat—After the subfloor has been prepared as hereinbefore specified and is thoroughly dry, the entire surface shall be covered with a first or prime coat of asphalt prepared and applied as follows: A known quantity of asphalt shall be placed in an open tank or kettle and heated to a temperature between 250 degrees and 300 degrees F. The fire shall then be drawn and an equal amount of gasoline (high test preferred), or benzine, shall be added to the hot asphalt and the mass thoroughly stirred. The mixture shall then be immediately applied while hot to the floor surface at the rate of ¼ gallon per square yard. No traffic shall be allowed on the treated surface and the material shall be allowed to remain in place for 3 or 4 hours, or until sticky, before applying the second coat.

Second Coat—There shall be provided a suitable platform for hand mixing and accurate measuring and weighing devices to insure the proper quantities of material being used. The asphalt shall be heated in an open kettle or tank to a temperature between 250 degrees and 325 degrees F. The aggregate shall be heated to a temperature between 225 degrees and 275 degrees F. After the materials are heated to the temperature specified they shall be placed on the mixing platform in the proportion of approximately one gallon of asphalt binder to 0.8 cubic foot of aggregate. The mass shall be thoroughly mixed by hand until all particles of the aggregate are entirely coated with the binder. The mixture shall then be placed immediately on the surface to be treated, spreading it evenly over the surface to the required depth. The entire surface shall then be hand tamped or rolled with a heavy hand roller.

Care shall be exercised to secure a smooth, even surface, free from depressions or irregularities, which when tested with a 10-foot straight-edge shall not vary by more than ¼ inch from the specified surface contour.

The total thickness of the asphalt mat coat shall be as specified but in no case shall exceed ¾ inch.

Application of Seal Coat to Tar or Mixed Asphalt Mats

After the second coat, for either tar or mixed asphalt mats, has been completed, the entire surface shall be given a seal coat of the same bituminous material as specified for the second coat. The bituminous material shall be applied hot and spread evenly over the surface by means of squeegees at the rate of ¼ gallon per square yard. After the seal coat has been applied, a light dressing of clean dry sand, stone screenings or granulated slag shall be spread evenly over it to absorb any excess bituminous material remaining on the surface. In order to hold the maintenance of this type of construction to a minimum, a double liquid seal coat is recommended.

Construction of Asphalt Mat Surface (Penetration Method)

Prime Coat—The first or prime coat of asphalt shall be prepared and applied in the same amount and manner as above specified for the prime coat for mixed asphalt mats.

Second Coat—After the first or prime coat has set sufficiently to become sticky the surface to be treated shall be covered with a thin layer of the aggregate applied over the surface by means of square pointed shovels.

The asphalt shall be heated in an open tank or kettle to a temperature between 250 degrees and 325 degrees F. and applied over the surface covered with the aggregate, at the rate of ½ gallon per square yard. The methods and appliances used shall be such as to insure a uniform distribution of the asphalt over the surface of the roadway. A suitable pressure spraying device, preferably, shall be employed. Care shall be taken not to overheat the material, the proper temperature being obtained when it will flow with reasonable freedom and remain fluid for a sufficient period to thoroughly penetrate the aggregate.

If successive applications of aggregate and asphalt are necessary to obtain the required thickness they shall be applied immediately following the first application. Each application shall consist of a layer of aggregate applied in the manner specified above and an application of hot asphalt applied at the rate of ¼ to ½ gallon per square yard.

Over the final coat of asphalt there shall be spread a layer of clean dry sand, stone screenings, or granulated slag sufficiently thick to prevent bleeding and the entire surface shall then be hand tamped or rolled with a heavy hand roller.

Care shall be exercised to secure a smooth, even surface, free from depressions or irregularities, which when tested with a 10 foot straight edge shall not vary by more than ¼ inch from the specified surface contour.

The total thickness of the asphalt mat coat shall be as specified but in no case shall exceed ¾ inch.

Opening to Traffic

No traffic shall be allowed on the bituminous mat surface for a period of 24 hours after it has been completed. Tar and mixed asphalt mats shall not be considered as completed until after the application of the seal coat.

Physical Properties

Tar

The first, or prime coat, (cold application), for tar wearing surfaces on wood bridge floors shall be a homogeneous tar conforming to the following requirements:

	Min.	*Max.*
Water, per cent	...	2.0
Specific viscosity (Note 1) Engler, 50 cc at 40° C. (104° F.)	8.0	13.0
Total bitumen soluble in carbon disulphide percent	88.0	...
Distillation test on water free material (Note 2):		
Total distillate, by weight—		
0–170° C. (32–338° F.) percent		7.0
0–270° C. (32–518° F.) percent		37.0
0–300° C. (32–572° F.) percent		45.0
Softening point of residue		60°C.

Note 1—Local conditions of temperature and of the surface to be treated may make advisable a change in the above specified viscosity. In case such change is made the following ranges of specific viscosity are suggested for use:

5–8; 8–13; 13–18; 18–25; 25–35.

Note 2—It is suggested that the maximum requirements for percentages of distillate for tars having a specific viscosity of 18–35 be as follows:

0–170° C.	5 percent
0–270° C.	30 percent
0–300° C.	40 percent

The second coat (hot application) for tar wearing surfaces on wood bridge floors shall be a homogeneous refined tar conforming to the following requirements:

	Min.	*Max.*
Water, percent	....	0.0
Float test at 32° C. (89.6° F.), seconds	150.0	210.0
Total bitumen (soluble in carbon disulphide) percent	80.0	....
Total distillate by weight:		
0–170° C. (32–338° F.) percent		1.0
0–270° C. (32–518° F.) percent		15.0
0–300° C. (32–572° F.) percent		25.0
Softening point of residue		65° C.

The Asphalts for Either Mixed or Penetration Method

Prepared from Petroleum

Specific gravity	not less than 1.0
Softening point	45–65° C.
Penetration	85–100
Loss at 163° C.—5 hours	Not more than 1%
Ductility	Not less than 50 C M
Soluble bitumen	Not less than 99.5%
Organic insoluble	Not more than 0.2%

Prepared from Native Asphalts

Specific gravity	Not less than 1.03
Softening point	45°–65° C.
Penetration	85–100
Loss at 163° C.—5 hours	Not more than 2.0%
Ductility	Not less than 30 C M
Soluble bitumen	Not less than 94.0%
Inorganic insoluble	2.5–4.0%

Aggregate for Cover Material

The aggregate shall be a clean, tough, durable crushed limestone, trap rock or other suitable stone having a percentage of wear of not more than 6; or a clean crushed slag weighing not less than 70 pounds per cubic foot when compacted to refusal by shaking; or a clean, hard, tough gravel, crushed or uncrushed, having a high resistance to abrasion. The aggregate shall be uniform in quality and gradation, free from dust, dirt, clay or other foreign matter. Two sizes, as tested with laboratory sieves shall be used as follows:

Coarse Aggregate Cover Material—The coarse aggregate cover material, No. 8¾-in. size, shall conform to the following gradation:

Sieve Size (Square Openings)	Total Percent Passing
1-in.	100
¾-in.	90–100
⅜-in.	30–65
No. 4	5–25
No. 8	0–5

Fine Aggregate Cover Material—The fine aggregate cover material, No. 8—⅜-in. size, shall conform to the following gradation:

Sieve Size (Square Openings)	Total Percent Passing
½-in.	100
⅜-in.	90–100
No. 4	10–30
No. 8	0–8

II

BITUMINOUS—CUT BACKS AND ASPHALT EMULSION

General requirements as given in Section 1 will apply to the use of these materials.

Prime Coat

After the floor has been cleaned and with use of bituminous cut backs, sufficient time should elapse for it to dry before application.

Prime Coat—Approximately ¼ to ½ gallon of bituminous content to the square yard and 24 hours shall elapse before application of the second coat.

In the use of tar cutback, and if practicable, it should be heated to a temperature of 125 deg. to 150 deg. F. to insure more complete penetration and adhesion to the floor.

Application by means of pressure distributors—steam or air—or by means of hand pouring pots.

Second Coat

These materials may be applied by the methods generally termed—Hot Surface treatment for tar; Cold Surface treatment, Mixed-in-Place or Penetration Construction.

Hot Surface treatment for tar to be as specified in Section 1.

Penetration Method will follow generally the construction as given in Section 1 except the asphalt materials shall not be heated.

Mineral aggregate used with bituminous cut backs shall be thoroughly dry before application or mixing is attempted.

Mineral aggregate shall be a clean, tough, durable limestone, trap rock or other suitable material having a percent of wear of not more than 5; or a clean crushed slag weighing not less than 70 pounds per cubic foot when compacted to refusal by shaking. The aggregate shall be uniform in quality and graduation and free from dust, dirt, clay and other foreign matter. When tested by means of laboratory sieves it shall conform to the following sizes:

Passing ¾-in. screen, not less than 95 percent by weight.
Passing ½-in. screen, 25 percent to 75 percent by weight.
Passing ¼-in. screen, not more than 15 percent by weight.

Where two course construction is required, the general range of sizes for the bottom course shall correspond to the following:

Passing 1½-in. screen—100 percent.
Passing ½-in. screen—10 percent to 35 percent by weight.
Passing No. 4 screen—4 percent to 16 percent by weight.

Mixed in Place Construction

The mixing shall preferably be done in a batch type concrete mixer, but if a mixer is not available it may be done by hand.

Machine mix—Correct quantity of aggregate shall first be put in the mixer, then proper proportion of the bituminous material added and this allowed to mix until all the aggregate is coated. The entire content of the drum shall be discharged before a new batch is started.

Hand mix—The mixing shall be done on a clean metal or wooden platform. Proper amount of aggregate shall be measured and right proportion of bituminous materials added. The pile shall be cut through from end to end until the aggregate is evenly distributed and uniformly coated.

Increasing density of the mix—If increase in density of the mix is desired, clean, coarse sand (dry if with tar) may be added, in which case the coarse aggregate shall be mixed as above. The sand shall then be added and the mixing continued until the entire aggregate is evenly distributed and uniformly coated.

Curing and Storing

In storing bituminous cut back mixed materials for curing, preparatory to use, the depth of the curing pile shall vary according to the length of time the mix is to be stored. If the mix is prepared in comparatively small quantities for immediate use, it shall be stored on clean metal or wooden platforms in piles not to exceed 12 inches in thickness, for a period of from 2 to 5 days. If storage is to be for a longer time, the piles may be made of any depth. A crust will form over the pile, but in rehandling from the storage point to the job the crust will mix with the softer materials underneath and the whole will be in condition for use.

While curing, the mix shall be stored under a shed or protected from rain by tarpaulins or other satisfactory covering, but shall be left uncovered during good weather to permit thorough curing.

Bituminous cut-back products that contain an inflammable solvent should be kept away from open flames.

Emulsified asphalt, except grades specifically prepared shall not be exposed to freezing temperatures and all bituminous material received in barrels shall be thoroughly mixed before use.

Proportion of Mix

The bituminous material for aggregates 1 inch or less shall have the following proportion per cubic yard.

Bituminous cut-backs .....12 to 16 gallons
Emulsified asphalts .....20 to 27 gallons

In two course construction when larger size aggregates are used, the quantities of the bituminous material may be reduced by 25 percent. The above approximately accounts for emulsifying agent and water in emulsions containing asphalts ranging from 55 to 75 percent.

Seal Coat

Materials and application as in Section 1 except for emulsified asphalts use damp sand mixed 1½ gallons per cubic foot, spread or brushed evenly over the surface and no attempt made to build a layer, but only to fill voids and seal the wearing course.

Emulsified Asphalt, Physical Properties

No.	Test of Emulsion	Type I	II	III	IV	V
1.	Viscosity, Furol, 60 ml.25°C. Seconds..	100–700	20–100	.....	.....	20–100
2.	Residue by distillation, percent.....	60–65	55–60	(1)	(1)	55–60
3.	Settlement, 5 days, not more than, percent	5	5	.....	.....	3
4.	Demulsibility, percent	0–30	0–30	.....	.....	50–100
5.	Freezing test, 3 cycles	.....	.....	.....	(2)	.....
6.	Sieve test, not more than, percent.. ..	0.20	0.20	0.20	0.20	0.20
7.	Mixability with water, no appreciable separation in ———— hours	2	2	2	2	.....
8.	Coating test	(3)	(3)	(3)	(3)	.....
	Test on Residue From Distillation Test					
9.	Penetration at 25°C. (77°F.) 100 grams 5 seconds	100–200	100–200	100–200	125–225	100–200
10.	Soluble in carbon disulphide—not less than, percent	95	95	95	95	95
11.	Ash—not more than, percent	2	2	2	2	2
12.	Ductility at 25°C. (77°F.) not less than, centimeters	40	40	40	40	40
13.	Specific gravity at 25°C. (77°F.) not less than	1.00	1.00	1.00	1.00	1.00

Note: (1) Not less than—65.
Note: (2) Homogeneous
Note: (3) Shall show no appreciable separation in three minutes.
Note: Methods of test—ASTM D-244—Adjustment of above requirements to tentative ASTM D-397, 398, 399 and 401.

Type I—Open-graded coarse aggregate plant mixtures
Type II—Open-graded coarse aggregate mixed-in-place construction
Type III—For summer use in bituminous concrete mixture for repair work
Type IV—For winter use in bituminous concrete mixtures for repair work
Type V—Penetration macadam and surface treatment work.

III

BITUMINOUS CONCRETE—COLD ASPHALT CONCRETE—LIQUEFIER TYPE

Description

This item shall consist of a "Wearing Course" and a "Bottom Course" premixed for cold-laid asphaltic concrete and furnished in separate lots for the quantities as specified with the coarse aggregates, fine aggregates, hydrated lime, liquefier and asphaltic cement, combined in such proportion as to be within the following general range limits.

General Composition of the Mixtures

The mineral aggregate shall be so graded and the prescribed constituents, prepared as detailed hereinafter, shall be combined in such proportion as to produce a mixture conforming to the following composition limits by weight.

Proportionate Amount (Square Mesh Sieves)	*Bottom Course Percent**	*Wearing Course Percent*
Aggregate passing 1½-in.	100	.....
Aggregate retained on 1¼-in.	0–5	.....
Aggregate retained on ½-in.	.....	0–5
Aggregate passing ½–in.	10–35	.....
Aggregate passing No. 4	4–16	15–40
Aggregate passing No. 8	.....	10–25
Aggregate passing No. 20	.....	5–15
Liquefier	0.2–1.5	0.2–1.5
Hydrated Lime	0.4–1.0	0.5–1.0
Asphalt (Sol. CS_2)	3.0–6.0	4.0–8.0

* Bottom course materials to be used only where thickness is greater than one inch and generally for laminated floor construction and alternate sized edge placed boards are used.

Formula given is a general range of tolerance. This formula may be adjusted to conform to the state highway specifications in general use at the respective location of the company submitting proposals for railway use. The formula as proposed to be used will be furnished, giving type and percent limits for the asphalt and kind of aggregate, with the range of grading wear and toughness. When slag is used for the aggregate, a definite statement is to be given for the percentage of filler added to compensate for its porosity.

Materials

Asphalt Cement—The asphalt cement shall be homogeneous, free from water, shall not foam when heated to a temperature of 347° F., and shall conform to the following requirements:

(a)	Penetration at 77°F., 100g., 5 sec.	85–100
	Total bitumen (soluble in carbon disulphide), not less than*	95.0%
	Proportion of bitumen soluble in carbon tetrachloride, not less than	99.0%
	Ductility at 77°F., not less than	30 cms.
	Flash point, not less than	347°F.
	Loss at 325°F., 5 hours, not more than	3.0%
	Penetration of residue at 77°F., 5 sec., as compared to penetration before heating, not less than	50.0%

* For Bermudez asphalt cement.

(b)	Penetration at 77°F., 100g., 5 sec.	85–100
	Total bitumen (soluble in carbon disulphide) not less than*	99.5%
	Proportion of bitumen soluble in carbon tetrachloride, not less than	99.0%

* For asphalt cement produced from petroleum.

Ductility at 77°F., not less than	30 cms.
Flash point, not less than	347°F.
Loss at 325°F., 5 hours, not less than	1.0%
Penetration of residue at 77°F., 5 sec., as compared to penetration before heating, not less than	60.0%

Mineral Aggregate—Mineral aggregate shall consist of clean, tough, durable crushed rock, excluding all but fractured particles, and showing a percentage of wear not greater than 6, and toughness of not less than 6, or air cooled, blast-furnace slag, having a weight per cubic foot not less than 70 pounds.

Hydrated Lime—Hydrated lime shall meet the requirements of the ASTM Standard Specifications, designation, C6–34T.

Liquefier—The liquefier shall meet the following requirements:

1. *During warm weather*—This naptha shall be a petroleum distillate which, when distilled in accordance with ASTM D86 shall have an initial boiling point of not over 220 deg. F. and an end point of not over 450 deg. F. At least 45 percent and not more than 55 percent of the distillate shall be distilled over 325 deg. F.

2. *During cold weather*—This naptha shall be a petroleum distillate which when distilled in accordance with ASTM D86 shall have an initial boiling point of not over 270 deg. F. and an end point lying between 425 deg. F. and 450 deg. F.

With regard to naphtha No. 2, the distillate shall go over continuously at regular intervals between 275 deg. F. and the end point so as to give a line on the distillation graph nearly straight.

Preparation and Transportation

Preparation of Bituminous Material—The bituminous material shall be heated in the melting kettles or tanks so as to secure even heating of the entire mass. The material shall be heated to between 200 deg. F. and 300 deg. F.

Preparation of Aggregates—All aggregate shall be dried to the extent that it has no surface moisture and not more than 0.4 percent of contained moisture. Mixing temperatures of the aggregate shall at no time be less than 45 deg. F. nor more than 110 deg. F., except that when using slag aggregate, the upper limit be raised to 126 deg. F.

Preparation of Mixture—The dried mineral aggregate, prepared as hereinafter described, combined in batches by weighing each separated and screened size, shall be conveyed to the empty mixer. The quantity or character of liquefier used shall be varied within the limits hereinbefore set forth, depending on weather, time and distance the material is to be transported, and shall be used in such manner as will insure the desired constituency of mixture when it is delivered on the project. The aggregate shall be mixed dry for a period sufficient to uniformly distribute the various sizes throughout the batch, after which liquefier shall be sprayed over the aggregate and the mixing continued until all the stone is coated.

The asphalt cement and hydrated lime shall then be successively introduced and the mixing continued until the mixture is thoroughly uniform and homogeneous in character. The dry mixing period shall be set in relation to the aggregate used and the total mixing time will vary in relation to the nature of the aggregates, and the capacity of the mixer but in no case shall the mixing time after the introduction of the asphalt be less than 2 minutes. The mixture shall be so prepared that it may be unloaded and applied at the prevailing temperature down to an air temperature of 45 deg. F., without application of heat.

The mixture shall be uniform in composition, free from lumps or balls of material containing an excess quantity of asphalt and free from pockets containing less asphalt than required. Mixtures for the bottom course and for the wearing course shall be mixed and handled separately.

Transportation of Mixture—All cars shall be in good condition and preferably without pockets. All projecting spikes, nails, foreign material and other obstructions likely to interfere with efficient unloading shall be removed from cars. The bottom of the cars shall be covered with a thin layer of clean sand or screenings. Loaded cars shall be covered with paper or other suitable material; trucks shall be covered with waterproof canvas covers when so ordered. The inside surface of the trucks may be thinly coated with a soapy water, or a mixture of water with not more than 10 per cent of lubricating oil. The use of kerosene, gasoline or similar products will not be permitted.

Shipments found to contain a surplus amount of bituminous material in the bottom of the car or truck will be rejected upon arrival.

Construction

(a) *Prime Coat*—After the subfloor has been prepared as hereinbefore specified and is thoroughly dry, the entire surface shall be covered with a prime coat of asphalt prepared and applied as follows: A known quantity of asphalt shall be placed in an open tank or kettle and heated to a temperature between 250 deg. and 300 deg. F. The fire shall be drawn and an equal amount of gasoline (high test preferred), or benzine, shall be added to the hot asphalt and the mass thoroughly stirred. The mixture shall then be immediately applied while hot to the floor surface at the rate of ¼ gallon per square yard. No traffic shall be allowed on the treated surface and the material shall be allowed to remain in place for three or four hours, or until sticky, before applying the bottom course.

(b) *Bottom Course*—If at the time of laying the surface course mixtures, permanent side support, such as curbs, edging, or gutters have not been constructed, planks of suitable thickness shall be laid along each side and rigidly supported so as to prevent the mixture from being displaced. These planks shall remain in place until final compaction has been obtained. Prior to the arrival of the wearing course mixture on the work, the bottom course shall have been cleaned of all loose and foreign material. The wearing course mixture shall be laid only on a bottom course which is dry, and only when weather conditions are suitable.

Whenever conditions permit, an approved finishing machine shall be used for spreading and leveling both the bottom and wearing courses. Should hand methods of handling and spreading be necessary, the following methods will be required:

Upon arrival on the work, the bottom course mixture shall be deposited on a dumping board outside of the area on which it is to be spread, then spread by suitable means in a uniformly loose layer weighing not less per square yard, per inch designed thickness, than the weight given for the bottom course mixture using aggregates of the specific gravity indicated. Measuring blocks or strips shall be used to insure an even distribution. In special isolated cases, it may be necessary to increase the thickness of the bottom course where laid on uneven wood floors. If such is ordered and the bottom course, measured loose, is of greater depth than 3 inches, it shall be laid and compacted in 2 layers.

For handling and spreading the mixture after being dumped from delivering vehicles on the work, the workmen shall be provided with suitable forks. As soon as practicable after the aggregate is spread, the surface shall be hand tamped or rolled with a heavy hand roller.

The mixture shall be kept clean at all times; dirt or foreign material shall not be allowed to mix with, under, or on the mixture while being unloaded, spread, tamped or rolled. Irregularities in the bottom course shall not exceed ¼ inch as measured with a 10-foot straightedge.

(c) *Wearing Course*—After the compacting of the bottom course, the wearing course shall be spread by forks or other approved methods in a uniformly loose layer so as to cover the underlying course and fill all voids therein. The weight of the wearing course mixture shall be not less per square yard, per inch designed thickness, than the weight of one course mixture as given for the specific gravity of the aggregates used, plus the weight of 0.1 inch (for penetration of top into bottom course).

The compacted bottom course should be covered by the wearing surface as soon as practicable, but not later than 24 hours after it is compacted.

After the wearing course has been spread uniformly even, the entire surface shall then be hand tamped or rolled with a heavy hand roller. If low spots appear in the surface course during compacting, additional mixture shall be spread and the compacting continued until the surface is regular and of even texture. The weight per square yard of the finished two-course surface mixture shall be not less than the weight per square yard, per inch designed thickness, for the bottom and wearing courses, including the allowance for the penetration of the wearing course material into the bottom course.

For the purpose of testing the finished surface, a 10-foot straightedge shall be available on the work. The surface of the top course shall be tested with the straightedge laid parallel to the center line of the roadway upon any portion of the surface, and any depression or other irregularities exceeding ¼ inch shall be satisfactorily eliminated. Such portions of the completed surfaces as are defective in any respect shall be removed and replaced with suitable material.

Upon the compacted wearing surface there shall be spread a layer of clean, dry sand, stone screenings or granulated slag sufficiently thick to prevent bleeding and the entire surface shall then be hand tamped or rolled with a heavy hand roller.

The application of the screenings shall follow the compacting or rolling, of the wearing surface as closely as is practicable, but never on a wet surface.

(d) *A One-Course Surface*—A one-course surface, when specified, shall be constructed of the wearing course mixture directly on the prime coat. The weight of the mixture shall be not less per square yard, per inch designed thickness, than the weight for one-course mixture as given for the specific gravity of the aggregate used. The construction shall be carried out in accordance with the provisions for placing the wearing course of the two-course pavement, the finish, final compression, and testing to be in accordance with the provisions for placing the wearing course of the two-course pavement.

(e) *Extensive Areas*—Where extensive areas of wood floors are to be covered with bituminous materials; or when the wood floor highway bridge is within the limits of highway bituminous material paving projects; after the entire wood surface has been treated with prime coat as specified, the bituminous concrete will be applied to the wood floor under the specifications applying to highway paving projects.

(f) *Protection of Surface Course*—The surfaces shall be protected from traffic until permission is given by the Engineer for the roadway to be opened to traffic.

(g) *Seasonal and Weather Limitation*—No material shall be placed when the air temperature in the shade is below 50 deg. F., except by written permission of the Engineer.

IV

COLD-LAY TAR-CONCRETE PAVEMENT TWO-COURSE CONSTRUCTION

This shall consist of a pavement composed of two courses of cold-laid tar-concrete constructed on a prepared floor.

Composition of mixtures—The several mixtures shall have the following composition:

For Use In	*Bottom Course*	*Top Course*
Tar Binder, percent by weight	2.5 to 4.5	6.5 to 9.0
Mineral Aggregate, percent by weight	95.5 to 97.5	91.0 to 93.5

Grading of Aggregate. The total mineral aggregate of the several mixtures, when tested by means of standard laboratory sieves with square openings, shall meet the following requirements, as designated:

For Use In	*Bottom Course*	*Top Course*
Size of Mixture	Intermediate	Fine
Passing No. 200 sieve, percent	.....	0–8
Passing No. 8 sieve, percent	0–5	25–50
Passing No. 4 sieve, percent	0–10	40–70
Passing ⅜-inch sieve, percent	.....	90–100
Passing ½-inch sieve, percent	10–70	100
Passing 1-inch sieve, percent	70–100	.....
Passing 1½-inch sieve, percent	100	.....

Uniformity. The several composition limits given above are master ranges of tolerance to govern mixtures made from any raw materials or combinations thereof, proffered for use under these specifications and they are maximum and minimum for all cases. A closer control within these ranges is intended for any specific project. No work shall be started on any specific project nor any mixture accepted, therefore, until the Contractor has submitted and received approval of his intended job mix, indicating in writing the single, definite percentage for each screen and sieve fractions and percent of tar which he chooses as a fixed mean for the project. The submission of such job mix shall, upon approval and thereafter, bind the Contractor to furnish a paving mixture not only within the above master ranges, but also meeting the exact mean percentages thus set up for the project, within allowable job tolerance of: plus or minus ½ percent for tar, plus or minus 10 percent for the ⅜-inch, and for larger sieve requirements, and plus or minus 5 percent for the No. 8 and for the small sieve requirements.

Materials

Tar Binder—The tar binder shall conform to the following requirements:

Sp. Gr., 25°/25° C. ..... Not less than 1.14
Float Test at 50° C., Sec., (Note A) ..... 40 to 120
Bitumen (Sol. in Car. Disulph.), % ..... Not less than 75
Distillation, percent by weight:

To 170° C. ..... Not more than 1.0
To 270° C. ..... Not more than 15.0
To 300° C. ..... Not more than 25.0

Soft. Pt., Ring and Ball,
Distillation Residue, °C. ..... 40 to 65.0

Note A: Tar binder used in mixtures for bottom course shall have a float test at 50 deg. C. of not less than 70 seconds. Tar binder used in mixtures for top course shall have a float test at 50 deg. C. of not less than 70 seconds, except that the Engineer may direct that the binder used in top course mixtures shipped in cars or for use in cool weather shall have a float test at 50 deg. C. of 40 to 80 seconds.

Broken Stone—The broken stone shall consist of clean, durable, and angular fragments of rock or boulders, free from an excess of flat or elongated pieces, soft or disintegrated stone, dirt, or other objectionable material. Broken rock shall be produced from rock having a percentage of wear of not more than 6.

The broken stone used in the several mixtures shall be well-graded between the limits of their nominal size, and may be one product or a combination of products of the screening plant which, when combined with filler as specified below, will produce total mineral aggregates for the several mixtures as hereinbefore specified.

Filler—The filler shall consist of sand, rock dust, slag dust, rock screenings or combinations therefore, all of which shall pass a No. 4 sieve, and not less than 75 percent of which shall pass a No. 8 sieve.

Preparation and Transportation

Drying and Temperature of Aggregate—The broken stone shall be dried in a rotating cylindrical dryer. The stone shall be heated by hot gases and not by direct flame to such a temperature and under such conditions that as it leaves the dryer, the stone will be surface dry and contain not more than ½ percent of contained water. Any wet or damp stone coming from the dryer shall be either re-run through the original dryer or through an auxiliary dryer. Covered storage bins for each size of dried stone shall be provided. When combined with the tar binder, broken stone shall be at a temperature not less than 65 deg. F. and not more than 110 deg. F.

Filler shall be sufficiently dry to be uniformly free-running so that there will be no "balling" when combined with other materials in the mixer. If necessary to drive off moisture by heating, it shall be allowed to cool to a temperature not in excess of 110 deg. F. before use. Rock dust shall be maintained in a substantially dry condition at all times and any material which is wet or contains lumps not readily broken up to powder in the mixer shall be discarded.

Heating and Temperatures of Tar Binder—The binder shall be heated by means of steam coils in the storage tanks to a temperature of 150 deg. to 225 deg. F. As used in the mixture, it shall be at as low a temperature within these limits as will permit thorough coating of the aggregate in a reasonable time. Heating tanks shall be equipped with suitable temperature indicating devices.

Preparation of Mixture—All mixtures shall be proportioned by weight. The components of mixtures shall be conveyed into the empty mixer. In no case shall the mixing time (hereby defined as the interval between the moment when all the ingredients are in the mixture and the opening of the discharge gate) be less than one minute.

The various sizes of broken stone shall be mixed dry for a period sufficient to distribute the various sizes throughout the batch; after which tar binder shall be added through a spray bar with openings at regular intervals over the full width of the mixer or slowly in a thin sheet the full width of the mixer. In preparing fine mixtures, the broken stone shall be thoroughly coated with binder before adding filler, which shall be uniformly distributed over the entire width of the mixer. The mixing operation shall then be continued for the specified time before opening the discharge gate.

The mixture shall be uniform in composition, free from lumps or balls of material containing an excess quantity of tar and free from pockets containing less tar than required.

Transportation of Mixtures—Shipment in cars, trucks, or wagons to follow generally the provisions as given in Section 3 for one or two-course construction.

Placing Bottom Course—Mixtures shall be laid only where the surface to be covered is dry and only when weather conditions are suitable. The contact surfaces of all curb-

ings and of adjacent pavement edges shall be painted or sealed with approved bituminous material.

Before any rolling is started, the finished surface struck by the machine shall be checked, any inequalities adjusted, all "drippings" i.e., fat sandy accumulations from the screed, and all fat spots from any source, shall be removed and replaced by satisfactory material.

When hand spreading is necessary, the mixture, upon arrival, shall be dumped on approved dump sheets outside of the area on which it is to be spread and shall then be immediately distributed into place by means of suitable shovels and other tools and spread with rakes in a uniformly loose layer of such depth as will result in a completed pavement having the weight per square yard required. Any deviation from standard section shall be immediately remedied by placing additional material or removing surplus as directed.

The material shall then be tamped or rolled and if any depressions appear they shall be filled immediately with additional bottom course mixture and again tamped or rolled until the surface is brought to the required grade and cross-section.

The finished surface of the bottom course shall be such that it will not vary more than ¼ inch from the cross-section of the road, nor from a 10-foot straight edge applied parallel to the center line of the pavement.

Placing Top Course—After the bottom course is compacted, the top course mixture, consisting of the fine mix as hereinbefore described, shall be spread through mechanical spreaders or from dumping boards in a uniform layer to a depth of not more than one inch loose so as to cover the underlying bottom course, fill all voids therein, and produce a completed pavement when rolled or tamped.

If depressions remain after rolling or tamping, more of the mixture shall be added at such points, and firmly compacted into place. After the compacting has been finished, the surface of the top course shall have the required density and thickness and be at the grade established for the surface of the finished pavement.

The finished pavement shall be such that it will not vary more than ¼ inch from the cross-section of the road, nor from a 10-foot straight edge applied parallel to the center line of the pavement.

Protection of Top Course—After the completion of the wearing course, no vehicular traffic of any kind shall be permitted on the pavement until it shall have set sufficiently, and in no case less than 24 hours after placing the bituminous wearing surface.

The report is offered as information, with the recommendation that the subject be continued.

REPORT OF COMMITTEE 8—MASONRY

J. F. Leonard, *Chairman;*
F. E. Bates,
H. F. Bober,
G. E. Boyd,
Maurice Coburn,
T. L. Condron,
Hardy Cross,
G. H. Dayett,
Theodore Doll,
G. F. Eberly,
W. K. Hatt,
R. Hayes,
Meyer Hirschthal,
L. H. Hornsby,
A. C. Irwin,
J. E. Kalinka,
J. A. Lahmer,
C. P. Marsh,
O. V. Parsons,
I. L. Pyle,
W. M. Ray,
G. W. Rear,
J. L. Rippey,
F. B. Robins,
G. E. Robinson,
C. P. Schantz,
A. N. Laird, *Vice-Chairman;*
*L. W. Skov,
G. R. Smiley,
A. W. Smith,
H. H. Temple,
J. H. Titus,
Jamison Vawter,
L. W. Walter,
C. A. Whipple,
W. R. Wilson,
H. A. Wistrich,
J. J. Yates.
Committee.

* Died November 16, 1938.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Specifications and principals of design of plain and reinforced concrete for use in railway bridges, buildings and culverts, collaborating with Committee 1—Roadway and Ballast, 5—Track, 6—Buildings, 7—Wood Bridges and Trestles, 13—Water Service, Fire Protection and Sanitation, and 15—Iron and Steel Structures (Appendix B).

(a) Concrete columns and pipe columns—Progress in study—no report.

(b) Rigid frame bridges as related to multiple spans—Progress in study—no report.

(c) Concrete bridge deck slabs of the non-ballast type, collaborating with Committee 5—Track—Progress in study—no report.

(d) Special types of steel reinforcement—Complete and presented as information.

3. Progress in the science and art of concrete manufacture (Appendix C).

(a) Prestwood, plywood, and special fibrous materials for forms and form lining. Complete and presented as information.

(b) Standard Portland cement compared to standard high-early-strength Portland cement. Complete and presented as information.

(c) Needed adjustments in field practice to use present-day cements to best advantage—Progress in study—no report.

4. Maintain contact with Joint Committee on Concrete and Reinforced Concrete—Progress in study.

5. Specifications for foundations, including excavation, cofferdam, piling, etc., collaborating with Committee 1—Roadway and Ballast on soil mechanics, and with Committee 7—Wood Bridges and Trestles on bearing power of wood piles and pile driving (Appendix D). "Specifications for Pile Foundations" Articles 1 to 5, inclusive, are submitted for adoption and publication in the Manual, Articles 6 to 8, inclusive, are offered as information.

6. Methods and practices of lining and relining tunnels, collaborating with Committee 1—Roadway and Ballast (Appendix E). Progress report, presented as information.

7. Specifications for placement of concrete by pumping (Appendix F). Recommended for adoption for inclusion in the Manual.

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8. Review specifications for overhead highway bridges of the American Association of State Highway Officials in so far as they relate to masonry, conferring with that association, and Committee 15—Iron and Steel Structures. No call during year by AASHO for collaboration.

9. Rating of reinforced concrete bridges—Progress in study—no report.

10. Investigation of the merits of the vacuum method of treatment of concrete after placement (Appendix G). Complete and presented as information.

11. Study and investigate suitability of steel beam bearing piles. Report presented under assignment 5 (Appendix D).

12. Progress in cement manufacture and testing—Progress in study—no report.

13. Specifications for concrete culvert pipe (Appendix H). Presented for adoption and publication in the Manual.

14. Recent discussions of the prestressing of reinforced concrete (Appendix I). Presented as information.

The Committee on Masonry,
J. F. Leonard, *Chairman.*

Lauritz Walter Skov

It is with profound regret that the Masonry committee records the passing of L. W. Skov, a member of the Association since 1922, and a member of the committee since 1924, who died at his home in Chicago, on November 16. Mr. Skov was born at Alden, Minn., on March 9, 1885, and was educated at Grand View College, Des Moines, Iowa, and Armour Institute of Technology, Chicago. Except for a short period with the Illinois Central, his entire professional career was with the Chicago, Burlington & Quincy, entering the bridge department of that road in November, 1906, and advancing through various grades to chief designer on June 1, 1918. On February 10, 1919, he was appointed terminal viaduct engineer and two months later was advanced to office engineer in the chief engineer's office, holding this position until August 20, 1929, when he was appointed special engineer of design on the grade separation project at Canal and 16th streets, Chicago. Upon the completion of this work in 1931, he returned to his former position of office engineer, and in 1936, he was appointed hydraulic engineer, the position he held at the time of his death.

Mr. Skov was active in the work of the Masonry committee, where his experience in the design and construction of both steel and concrete structures and his natural resourcefulness enabled him to be particularly helpful. His loss will be felt deeply by the Association, which he served faithfully, not only as a member of the Committee on Masonry, but also as a member of the Committee on Economics of Bridges and Trestles and of the Committee on Waterways and Harbors.

Appendix A

(1) REVISION OF MANUAL

G. E. Boyd, Chairman, Subcommittee; F. E. Bates; T. L. Condron, Meyer Hirschthal, L. H. Hornsby, A. C. Irwin, J. A. Lahmer, F. B. Robins, C. P. Schantz, C. A. Whipple, J. J. Yates.

The committee recommends the deletion of Section 2, Fineness, in the Specifications for High-Early-Strength Portland Cement, page 8–5 of the Manual, and of paragraph (c) of Section 9, page 8–6 of the Manual, relating to the rejection of cement for failure to meet the fineness requirement.

Section 3 and subsequent sections to be renumbered and paragraphs (d) and (e) of Section 9 to be redesignated as (c) and (d) respectively.

The ASTM designation to be changed to C74–37 and the asterisk to be deleted from the head.

Delete Footnote 1 on page 8–7 and renumber subsequent footnotes and their references.

The committee recommends the deletion of Section 1, 3 and 13, of the Specifications for Portland Cement, appearing on pages 8–9 and 8–10 of the Manual, the addition of a paragraph and note to Section 2, the redesignation of this section as Section 1 and the renumbering of all subsequent sections. These deletions and additions are as follows:

To Be Deleted

1. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination, excepting water and calcined or uncalcined gypsum.

3. The residue on a standard No. 200 sieve shall not exceed 22 percent by weight.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100 deg. C., for 1 hour it meets this requirement.

Proposed Form

Chemical Limits

1. The following maximum limits shall not be exceeded by amounts greater than the respective tolerances indicated as allowable in the chemical determinations:

	Limits percent	*Tolerances percent*
Loss on ignition	4.00	0.25
Insoluble residue	0.85	0.15
Sulfuric anhydride (SO_3)	2.00	0.10
Magnesia (MgO)	5.00	0.40

Portland cement is the product obtained by pulverizing clinker consisting essentially of calcium silicates, to which no additions have been made subsequent to calcination other than either water or untreated calcium sulfate, or both, except that additions not to exceed 1 percent of other materials may be added, provided such materials have been shown not to be harmful by tests prescribed and carried out by committee C–1 on Cement.

Note.—Tests to determine whether a proposed addition is harmful will be carried out by Committee C–1 on Cement for those making requests, through its Cement Reference Laboratory or other laboratory which the committee may select. As such tests are completed the committee will make known these additions which have been found not to be harmful. (For details regarding the conditions under which the tests will be made, address Technical Assistant, Committee C–1, Cement Reference Laboratory, National Bureau of Standards, Washington, D. C.)

The ASTM designation to be changed to C9–38*.

Delete Footnote 1 on page 8–10.

The committee recommends that Sections 8 to 11, inclusive, in the Standard Methods of Sampling and Testing Portland Cement, pages 8–12, 8–13 and 8–14 of the Manual, be withdrawn and that new requirements for the procedures for chemical analysis be substituted as follows:

To Be Deleted

Loss on Ignition

8. One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25-cc. capacity, as follows, using either Method A or B, as specified:

Method A:

The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about 3/5 of the crucible projects below, and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

Method B:

The crucible shall be placed in a muffle at any temperature between 900 degrees and 1000 degrees C. for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

Proposed Form

Loss on Ignition

8. Heat a 1-g., sample of cement in a weighed covered platinum crucible of 20 to 25-ml. capacity, as follows, using either Method 1 or 2 as specified.

(a) Method 1.—Place the crucible in a hole in an asbestos board, clamped horizontally, so that about three fifths of the crucible projects below the board, and heat at a full red heat (900 to 1000 C.) for 15 minutes; check the loss in weight by a second heating for 5 minutes. Take care to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating may be secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

(b) Method 2.—Place the crucible in a muffle furnace at any temperature between 900 and 1000 degrees C. for 15 minutes and check the loss in weight by a second heating for 5 minutes.

To Be Deleted

Insoluble Residue

9. To a 1-gram sample of cement shall be added 25 cc. of water and 5 cc. of concentrated HCl (sp. gr. 1.19). Material shall be ground with the flattened end of a glass rod until it is evident that the decomposition of the cement is complete. The solution shall then be diluted to 50 cc. and digested on a steam bath for 15 minutes. The residue shall be filtered, washed with cold water and the filter paper and contents digested in about 30 cc. of a 5 percent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with hot water, then with a few drops of hot HCl (1:9) and finally with hot water, then ignited at a red heat and weighed as the insoluble residue.

Proposed Form

Insoluble Residue

9. Add 25 ml. of cold water and 5 ml. of HCl (sp. gr. 1.19) to a 1-g. sample of cement. Heat the solution and grind the material with the flattened end of a glass rod until it is evident that decomposition of the cement is complete. Dilute the solution to 50 ml. and digest on a steam bath for 15 minutes. Filter the residue, wash six times with hot water, and digest the filter paper and contents in about 30 ml. of a sodium carbonate solution (5 percent), the liquid being held at a temperature just short of boiling for 15 minutes. Filter the remaining residue, wash twice with hot water, then with a few drops of hot diluted HCl (1:9), and finally eight to ten times with hot water, then ignite at a red heat and weigh as the insoluble residue.

To Be Deleted

Sulfuric Anhydride

10. To a 1-gram sample of cement shall be added 25 cc. of water and 5 cc. of concentrated HCl (sp. gr. 1.19). Material shall be ground with the flattened end of a glass rod until it is evident that decomposition of the cement is complete. The solution shall be diluted to 50 cc. and digested on a steam bath for 15 minutes, filtered, and the residue washed thoroughly with hot water. The solution shall be diluted to 250 cc., heated to boiling, and 10 cc. of a hot 10 percent solution of barium chloride shall be added slowly drop by drop, from a pipette and the boiling continued until the precipitate is well formed. The solution shall then be digested on the steam bath at least 3 hours, preferably over night. The precipitate shall be filtered, washed and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulfate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulfuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulfuric anhydride instead of using a separate sample.

Proposed Form

Sulfuric Anhydride

10. Add 25 ml. of cold water and 5 ml. of HCl (sp. gr. 1.19) to a 1-g. sample of cement. Heat the solution and grind the material with the flattened end of a glass rod until it is evident that decomposition of the cement is complete. Dilute the solution to 50 ml. and digest on a steam bath for 15 minutes, filter, and wash the residue thoroughly with hot water. Dilute the solution to 250 ml., heat to boiling, add slowly, drop by drop from a pipette, 10 ml. of a hot barium chloride solution (10 percent), and continue the boiling until the precipitate is well formed. Then digest the solution on the steam bath for at least 3 hours, preferably overnight. Filter the precipitate, wash and place the paper and contents in a weighed platinum crucible and slowly char and consume the paper without flaming. Then ignite, and weigh the barium sulfate. The weight obtained multiplied by 34.3 gives the percentage of sulfuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulfuric anhydride instead of using a separate sample.

To Be Deleted

Magnesia

11. To 0.5 gram of the cement in an evaporating dish shall be added 10 cc. of water to prevent lumping and then 10 cc. of concentrated HCl (sp. gr. 1.19). The material shall be ground with the flattened end of a glass rod until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration, the residue may be heated to 150 degrees C. or even 200 degrees C. for one-half to one hour. The residue shall be treated with 10 cc. of HCl diluted with an equal amount of water. The dish shall be covered, and the solution digested for 10 minutes on a steam bath or water bath. The solution shall be diluted to 75 cc., filtered into a beaker, and the separated silica washed thoroughly with hot water (Note 1). Five cubic centimeters of concentrated HCl (sp. gr. 1.19) and two drops of methyl red indicator (0.2 percent alcoholic solution) shall be added to the filtrate (about 250 cc.) (Note 2).

Note 1.—Since this procedure does not involve the determination of silica, a second evaporation is unnecessary.

Note 2.—Manganese, if present, is distributed between the precipitates of iron and alumina, calcium and magnesium. In the amount usually present in Portland cement, it may be neglected. If it is desired to determine the small amount of manganese that may be present in the magnesium pyrophosphate, this may be done colorimetrically as described in the U. S. Geological Survey Bulletin No. 700, p. 153. If present in larger amounts, manganese should be precipitated with the iron and alumina, preferably by the persulfate method (U. S. Geological Survey Bulletin No. 700, p. 112). If this method is used more aluminum passes into solution than in the method above prescribed.

Dilute ammonium hydroxide shall be added dropwise until the color of the solution changes to a distinct yellow. The solution shall be boiled for one or two minutes and filtered at once. The beaker and precipitate shall be washed slightly with a hot 2 percent solution of ammonium chloride (or ammonium nitrate). Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitating vessel and dissolved in 10 cc. of hot HCl. The paper shall then be extracted with acid, the solution and washings being added to the solution of the precipitate. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide as before in a volume of about 100 cc. and the second precipitate shall be collected and washed with a hot 2 percent solution of ammonium chloride (or ammonium nitrate) on the filter used in the first instance, if this is still intact. To the combined filtrates from the hydroxides of iron and aluminum, reduced in volume if need be, 1 cc. of ammonium hydroxide shall be added, the solution brought to boiling, 25 cc. of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well defined granular form. The precipitate after 1 hour shall be filtered and washed, and the filtrate set aside. The filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a bunsen burner; after ignition, it shall be cautiously moistened with water, redissolved in HCl and the solution diluted to 100 cc.; ammonia shall be added in slight excess, the liquid boiled, and filtered if a precipitate appears. The lime shall then be reprecipitated by ammonium oxalate, allowed to stand till settled, filtered and washed. The combined filtrates from the calcium precipitates shall be acidified with HCl, concentrated on the steam bath to about 150 cc. and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little iron and aluminum, and perhaps calcium). When cool, the solution shall be acidified with HCl, 10 cc. of saturated solution of sodium ammonium hydrogen phosphate added, and ammonia drop by drop, with constant stirring.

When the crystalline ammonium magnesium orthophosphate has formed, 5 cc. excess ammonia shall be added. The solution shall be set aside for not less than 4 hours, preferably over night, in a cool place, filtered and washed with water containing 2.5 percent NH_3. The precipitate shall be dissolved in a small quantity of hot HCl, the solution diluted to about 100 cc., 1 cc. of a saturated solution of sodium ammonium hydrogen phosphate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about 2 hours, filtered and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesium. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum, and manganese as phosphates.

Proposed Form

Silica

11. (a) Transfer a 0.5-g. sample of the finely powdered cement to an evaporating dish, preferably of platinum for the sake of celerity in evaporation, moisten with 10 ml. of cold water to prevent lumping, add 5 to 10 ml. of HCl (sp. gr. 1.19) and digest with the aid of gentle heat and agitation until solution is complete. Solution may be aided by light pressure with the flattened end of a glass rod. Evaporate the solution to dryness on a steam bath. Treat the residue without further heating at first with 5 to 10 ml. of HCl (sp. gr. 1.19) then diluting to half strength or less, or pour at once upon the residue a larger volume of acid of half strength. Then cover the dish and digest for 10 minutes on the bath or a hot plate. Dilute the solution with an equal volume of hot water, immediately filter, and wash the separated silica thoroughly with hot water and reserve. Again evaporate the filtrate to dryness, baking the residue in an oven 1 hour at a temperature of 105 to 110 degrees C. Then take up the residue with 10 to 15 ml. of diluted HCl (1:1) and heat on the bath or hot plate. Dilute the solution with an equal volume of hot water and catch and wash the small amount of silica it contains on another filter paper. Reserve the filtrate and washings. Transfer this paper and the reserved paper containing the residues to a weighed platinum crucible, dry, ignite first over a bunsen burner until the carbon of the filter paper is completely consumed without flaming and finally over a burner or in an electric oven at 1,100 to 1,200 degrees C. until the weight remains constant.

(b) Treat the silica thus obtained, which will contain small amounts of impurities, in the crucible with a few drops of water, about 10 ml. of HF and 1 drop of H_2SO_4, and evaporate to dryness over a low flame. Finally, heat the small residue at 1,050 to 1,100 degrees C. for a minute or two, cool, and weigh. The difference between this weight and the weight previously obtained represents the amount of silica. Washing of the silica precipitates can be made more effective by using a hot solution of diluted HCl (1:99), and then completing the washing with hot water. Consider the weighed residue, remaining after volatilization of the silica, as combined aluminum and ferric oxides and add it to the result obtained in the determination of these oxides (Section 12).

Ferric Oxide and Alumina

12. Treat the reserved filtrate (Note 1), which should have a volume of about 250 ml., with HCl, if necessary, to insure a total of 10 to 15 ml. of the acid, add a few drops of methyl red indicator and then heat to boiling. Then treat with NH_4OH (Note 2), drop by drop until one drop changes the color of the solution to a distinct yellow. Bring to boiling the solution containing the precipitated iron and aluminum hydroxides, boil for 1 or 2 minutes, and then filter. Wash the precipitate once by decantation and slightly on the filter with a hot ammonium nitrate solution (2 percent). Set aside the filtrate and transfer the precipitate and filter paper to the same beaker in which the first precipitation was effected. Then dissolve the iron and aluminum hydroxides in hot diluted HCl (1:3), make up the solution to about 100 ml., and reprecipitate the hydroxides as in the first case. Then filter the solution and wash the precipitate with two 10-ml. portions of a hot ammonium nitrate solution (2 percent). Combine the filtrate and washings with that set aside and place the precipitate in a weighed platinum crucible, slowly heat by a bunsen or Meker burner until the papers are charred, and finally ignite to constant weight at 1,050 to 1,100 degrees C. with care to prevent reduction, and weigh as $Al_2O_3 + Fe_2O_3$.

Note 1.—If a platinum evaporating dish has been used for the dehydration of silica, iron may have been partially reduced. At this stage, add about 3 ml. of saturated aqueous solution of bromine to the filtrate and boil the filtrate to eliminate the excess bromine before adding the methyl red indicator.

Note 2.—The NH_4OH used to precipitate the hydroxides must be free of contamination with carbon dioxide.

Ferric Oxide

The result for this method for determining ferric oxide is not affected by any titania or vanadium oxide that may be in the cement. It is therefore understood that these are counted as Al_2O_3 in this method. If the precipitations of aluminum and iron are made as directed, little if any manganese will be retained in the precipitate.

13. *Solutions Required.*—The following solutions will be required:

(a) Stannous Chloride.—Disolve 2 g. of the crystallized salt in four times its weight of a mixture of three parts of water and one of HCl (sp. gr. 1.19). Add scraps of iron-free granulated tin and boil until the solution is clear. Keep the solution in a closed dropping bottle containing metallic tin.

(b) Phosphoric Acid Mixture.—Add slowly and with stirring 150 ml. of orthophosphoric acid (sp. gr. 1.71), and 150 ml. of H_2SO_4 (sp. gr. 1.84), to 500 ml. of water and then dilute to 1,000 ml. with water and mix.

(c) Diphenylamine Indicator.—Dissolve 1 g. of diphenylamine in 100 ml. of H_2SO_4 (sp. gr. 1.84).

(d) Standard Potassium Bichromate Solution.—Dissolve 2.457 g. of $K_2Cr_2O_7$ in distilled water and dilute to 1 liter. Standardize against standard iron wire of known iron content in the same manner as directed for the ferric oxide determination in cement (Section 14), using a weight of iron wire which will yield a titration approximately equal to that required by the cement sample in question.

14. *Method.*—Add 20 ml. of cold water and 10 ml. of HCl (sp. gr. 1.19) to a 1-g. sample of cement. Heat the solution and grind the material with the flattened end of a glass rod until it is evident that decomposition of the cement is complete. Dilute the solution to 50 ml. and heat to boiling. Then treat the solution with 5 ml. of HCl (sp. gr. 1.19) and then with a solution of stannous chloride, added drop by drop while stirring until the solution is decolorized, then add one drop more. Cool the solution to room temperature, rinse the inside of the vessel with water and add all at once 10 ml. of a cool saturated solution of mercuric chloride. Then stir the solution vigorously for

1 minute, treat with 15 ml. of phosphoric acid mixture and three drops of diphenylamine indicator and dilute to 150 ml. with cold water. Then titrate with a standard potassium dichromate solution having a titer no greater than 0.004 g. of Fe_2O_3. The end point is taken as the point when a drop causes an intense deep blue coloration that remains unchanged in the further addition of the standard $K_2Cr_2O_7$ solution.

Calcium Oxide

15. Add a few drops of NH_4OH to the combined filtrates obtained in the alumina and ferric oxide precipitation (Section 12) and bring the solution to boiling. Add to the boiling solution 25 ml. of a boiling ammonium oxalate solution (5 percent), the boiling being continued until the precipitated calcium oxalate assumes a well-defined granular form. Then allow the solution to stand for about 20 minutes or until the precipitate is settled, filter, and moderately wash with an ammonium oxalate solution (0.1 percent). Reserve the filtrate and washings. Place the filter paper containing the precipitate wet, in a platinum crucible and burn off the paper over the small flame of a bunsen burner. Then ignite the precipitate until the oxalate is converted to oxide (Note), redissolve in HCl and make up the solution to 100 ml. with water. Add NH_4OH in slight excess and bring the solution to boiling. If a small amount of alumina separates at this point, filter it out, weigh, and add the amount to that found in the original alumina determination. Then reprecipitate the lime by ammonium oxalate, allow to stand until settled, filter, and wash, taking care to avoid an excess of the washing solution. Combine the filtrate with that already reserved. Weigh the precipitate as calcium oxide after ignition and blasting to constant weight in a weighed, covered platinum crucible.

Note.—If the ignited precipitate is darkly colored, it may contain an appreciable amount of manganese. The contamination of the second precipitate of calcium oxalate by manganese should be as low as possible. The following procedure may be used to reduce the contamination: Add 5 ml. of cold water cautiously to the precipitate and then cautiously add 10 ml. of diluted HCl (1:1). Heat the mixture. If the resulting solution is colored, digest it on the hot plate gently for 10 minutes or longer until the color disappears or until it is apparent the color will not become lighter on further heating. After a little practice it is possible to dissolve hard-burnt lime in this way without explosive spattering.

If the second precipitate of calcium oxalate is so fine as to cause difficulty in filtering or if the precipitate causes bumping, the volume of solution may be increased to 150 or 200 ml., instead of 100 ml., prior to precipitation.

Magnesia

In this method for determining magnesia, most of any manganese in the cement is precipitated with the magnesium. It is understood in this method that manganese so precipitated shall be calculated as magnesium.

16. Acidify the filtrates reserved in the determination of calcium oxide (Section 15) with HCl and concentrate to about 150 ml. Add to this solution about 10 ml. of diammonium phosphate solution (25 g. of the salt per 100 ml. of water) and boil the solution for several minutes. Then cool the solution by placing in a beaker of ice water. After cooling, add NH_4OH drop by drop, while stirring constantly until the crystalline ammonium-magnesium orthophosphate begins to form, and then in moderate excess (5 to 10 percent of the volume of the solution), the stirring being continued for several minutes. Set the solution aside for at least 8 hours in a cool atmosphere, and then filter. Redissolve the precipitate thus obtained in hot diluted HCl (1:4), make up the solution to about 100 ml., add 1 ml. of the solution of diammonium phosphate, and NH_4OH drop by drop, while stirring constantly until the precipitate is again formed as described, and the ammonia is in moderate excess. Then cool, allow to stand for about 2 hours, filter, and wash with two 10-ml. portions of wash solution (200 ml. of concentrated NH_4OH,

100 g. of ammonium nitrate, and 800 ml. of water), place in a weighed platinum crucible, slowly char the paper, and carefully burn off the resulting carbon. Ignite the precipitate at a temperature between 1,100 and 1,200 degrees C. to constant weight, taking care to avoid bringing the pyrophosphate to melting. The weight of magnesium pyrophosphate obtained multiplied by 72.4 gives the percentage of magnesia.

Blank Determination

17. Make a blank determination for sulfuric anhydride, silica, ferric oxide and alumina, ferric oxide, calcium oxide, and magnesia, using the same procedures as outlined in Sections 8 to 16, and using approximately the same amounts of reagents. Correct accordingly the results previously determined.

The committee recommends the inclusion in the specifications for Standard Methods of Sampling and Testing Cement, to follow Section 17 in the amended specification of the following:

Rapid Determination of Magnesia in Portland Cement

Note.—Either of the methods in Sections 18 to 21 may be used when magnesia alone is to be determined, except that in case of dispute the results obtained according to Section 16 shall govern.

Method A. Acid-Alkali Method for Rapid Determination of Magnesia.

Solutions Required

18. The following solutions will be required:

(a) Trinitrobenzene Indicator.—Dissolve 1.0 g. of c.p. 1–3–5 trinitrobenzene in 100 ml. of ethyl alcohol (95 to 100 percent).

(b) Phenolphthalein Indicator.—Dissolve 0.4 g. of c.p. phenolphthalein in 100 ml. of ethyl alcohol (50 percent).

(c) Standard Sodium Hydroxide Solution.—Dissolve 13.0 g. of sodium hydroxide in water, add 10 ml. of a freshly filtered saturated barium hydroxide solution, and dilute to 1 liter with distilled water which has been recently boiled and cooled. Shake the solution from time to time for several hours, and filter into a tubulature bottle fitted with an automatic burette. Protect the solution from carbon dioxide in the air, with soda-lime tubes at the top of the bottle and the burette.

The solution as prepared will be approximately ⅓ N. Standardize against acid potassium phthalate or benzoic acid acidmetric standards furnished by the National Bureau of Standards (Standard Samples Nos. 84 and 39), using the methods in the certificates accompanying the standard samples. Determine the exact normality of the solution, and calculate its MgO equivalent on the basis that 1 ml. of a normal solution is equivalent to 0.02016 g. of MgO.

(d) Standard Acid Solution.—Dilute 32.0 ml. of HCl (sp. gr. 1.19) or 26.0 ml. of HNO_3 (sp. gr. 1.42) to 1 liter with distilled water. This solution will be slightly in excess of ⅓ N. Standardize against the standard sodium hydroxide solution, using phenolphthalein indicator, and adjust by dilution until the two solutions are of equal strength.

(e) Potassium Iodide-Starch Paper.—Mix equal volumes of a 5 percent potassium iodide solution and a 1 percent soluble starch solution, and dip strips of filter paper into the mixture.

Procedure

19. (a) Add about 50 ml. of water and 50 ml. of diluted HCl (1:1) to 5.0 g. of cement in a 600-ml. beaker and boil the solution until the cement is completely in solution, excepting possibly some silica which may separate out (Note 1). Then add 5 ml.

of saturated bromine water and continue the boiling until the excess bromine is completely expelled, as indicated by the absence of a blue coloration on potassium iodide-starch paper when held in the issuing steam. Then dilute the solution to about 250 ml. with hot water and add NaOH solution (20 percent) to the boiling solution from a pipette, until the excess acid is neutralized and a permanent precipitate just forms. Continue the boiling, carefully add diluted HCl (1:1) from a pipette until the precipitate dissolves and the solution assumes a yellow ferric chloride color, avoiding much excess of acid. Wash down the sides of the beaker with hot water and continue the boiling for a minute or two, and then remove the beaker from the burner.

(b) Cautiously add to the solution 4.0 g. of calcium carbonate (weighed to the nearest 0.1 g.). This amount should be sufficient to completely neutralize the acid, with some excess. Dilute the solution to about 400 ml. with hot water and boil vigorously for about 10 minutes. Remove the beaker from the burner or hot plate, and from a burette carefully add potassium permanganate solution (0.5 percent) to the hot solution, while stirring vigorously, until the supernatant liquid shows a faint pink color after settling a moment. Avoid the use of more permanganate than necessary to produce a faint pink color. Continue the boiling for 2 minutes, add 2.0 ml. of ethyl alcohol, and continue the boiling for a few minutes or until the pink color has disappeared (Note 2).

(c) Transfer the contents of the beaker to a 500-ml. volumetric flask, cool to room temperature, dilute to the mark, and mix by shaking. Filter the solution through dry paper, and after discarding the first 10 or 20 ml. of filtrate, transfer 200 ml. of the filtrate with a pipette to a 500-ml. Erlenmeyer flask. Heat the solution in the flask to boiling and add 3.0 ml. of trinitrobenzene indicator. Then add standard sodium hydroxide solution, 1.0 ml. at a time, with intermittent boiling for a few seconds, until the magnesium is completely precipitated and a definite pink color persists on boiling. Record the total amount of alkali used. (Note 3).

(d) Transfer the solution to a 250-ml. volumetric flask, cool to room temperature, dilute to the mark, and mix by shaking. Filter the solution through a dry paper into a graduated cylinder, discarding the first 10 or 20 ml. of filtrate, until 125 ml. of the filtrate are secured. Transfer 125 ml. of the filtrate to a flask, add a few drops of phenolphthalein indicator, and titrate the solution with standard acid solution to the disappearance of the pink color.

(e) Calculation.—If the acid and alkali solutions are of equal strength, the quantity of alkali in milliliters minus twice the quantity of acid in milliliters is equivalent to the MgO in a 2-g. sample:

$$\text{MgO, percent} = \frac{100\,(a - 2b)}{2} \times c$$

where a = the quantity of standard alkali in milliliters,

b = the quantity of standard acid in milliliters, and

c = the MgO equivalent of 1 ml. of standard alkali.

Note 1.—Some samples of cement, particularly those containing considerable iron or manganese, may require longer boiling or the addition of slightly more HCl to effect complete solution.

Note 2.—The purpose of the addition of potassium permanganate is to remove manganese from the sample, which otherwise would be precipitated and reported as MgO. The permanganate in a hot solution oxidizes the manganese to insoluble MnO_2 and is itself reduced to MnO_2. The ethyl alcohol precipitates the excess permanganate. In samples containing little or no manganese, this portion of the procedure may be omitted.

Note 3.—Enough standard alkali should be added to completely precipitate the magnesium without too large an excess which might cause some precipitation of calcium. A guide to proper procedure is the amount of back titration with acid, which should be held between 1.0 and 2.0 ml. (after being doubled). A little experience with the color change of the trinitrobenzene indicator will enable the operator to hold the back titration between these limits.

Method B. Rapid Determination of Magnesia by Titration of Magnesium Oxyquinolate[3]

Solutions Required

20. The following solutions will be required:

(a) 8-Hydroxyquinoline (1.25 percent).—Dissolve 25 g. of 8-hydroxyquinoline in 60 ml. of glacial acetic acid. When the solution is complete, dilute to 2 liters with cold water. One milliliter of this solution is equivalent to 0.0016 g. of MgO.

(b) Sodium Thiosulfate Solution (0.1 N).—Dissolve 25 g. of $Na_2S_2O_3.5H_2O$ in 200 ml. of water and dilute to 1 liter. Standardize this solution either on sodium oxalate through a permanganate solution, or on arsenious oxide through a solution of resublimed iodine. Standard Samples Nos. 40 and 83 of the National Bureau of Standards are convenient for this purpose. One milliliter of exactly 0.1 N sodium thiosulfate solution is equivalent to 0.000504 g. of MgO.

(c) Potassium Bromate—Potassium Bromide Solution (0.2 N).—Dissolve 20 g. of KBr and 5.57 g. of $KBrO_3$ in 200 ml. of water and dilute to 1 liter. Obtain the ratio of this solution to the standard sodium thiosulfate solution as follows: To 200 ml. of water in a 400-ml. beaker add exactly 25 ml. of bromate solution. Add 20 ml. of HCl (sp. gr. 1.19), stir, and add immediately 10 ml. of Kl solution. Mix well and titrate at once with the sodium thiosulfate solution until nearly colorless. Add 2 ml. of starch solution, and titrate to the disappearance of the blue color.

(d) Potassium Iodide Solution (25 percent).—Dissolve 25 g. of Kl in 100 ml. of water.

(e) Starch Solution.—To 500 ml. of boiling water add a cold suspension of 5 g. of soluble starch in 25 ml. of water, cool, add a cool solution of 5 g. of NaOH in 50 ml. of water, add 15 g. of Kl and mix thoroughly.

Procedure

21. (a) Add 10 ml. of water and 10 ml. of HCl (sp. gr. 1.19) to a 0.500 g. sample of cement in a 400-ml. beaker. Heat gently and grind any coarse particles with the flattened end of a glass rod until decomposition is complete. Add hot water to make a total volume of 100 ml.

(b) Add 3 drops of methyl red (0.02 percent alcoholic solution) to the solution and then add NH_4OH (sp. gr. 0.90) until the solution is distinctly yellow. Heat this solution to boiling and boil for 1 to 2 minutes, then remove from the burner or hot plate, and allow to stand until the precipitation has settled. Filter the solution without delay and wash the precipitate twice with a hot solution of NH_4Cl (2 percent). Then transfer the precipitate with the filter paper to the beaker and dissolve in 10 ml. of diluted HCl (1:1). Dilute to about 100 ml. and heat to boiling. Reprecipitate, filter, and wash the hydrates as above. Add 1 ml. of NH_4OH (sp. gr. 0.90) to the filtrate. Heat the filtrate to boiling and while boiling add 25 ml. of a hot solution of $(NH_4)_2C_2O_4.H_2O$ (4 percent) and continue the boiling for 2 minutes. Continue the digestion on the steam bath for 10 to 15 minutes.

(c) Cool the solution to 70 C. and add 10 to 25 ml. of the 8-hydroxyquinoline reagent (Note 4) and then 4 ml. of NH_4OH (sp. gr. 0.90) per 100 ml. of solution. Stir the solution on a mechanical stirring machine for 15 minutes and set aside until the precipitate has settled (Note 5). Then filter the solution and wash the precipitate with hot diluted NH_4OH (1:40). Dissolve the precipitate in 50 to 75 ml. of the hot diluted HCl (1:9), dilute the resulting solution to 200 ml. and then add 15 ml. of HCl (sp. gr. 1.19). Then cool the solution to 25 C. and add 10 to 35 ml. of standard bromate solution (Note 6) from a pipette. Stir the solution and allow to stand for about 30 seconds to

insure complete bromination. Then add 10 ml. of the KI solution. Stir the resulting solution well and then titrate with the standard sodium thiosulfate solution until the color of the iodine becomes faintly yellow. At this point add 2 ml. of the starch solution and titrate the solution to the disappearance of the blue color.

(d) Calculation.—The percentage of magnesia in a 0.5-g. sample may be calculated as follows:

Percentage of MgO $= [(B - C) \times A] \times 200$

where A = the weight of MgO in grams per milliliter of standard sodium thiosulfate solution,

B = Milliliters of standard sodium thiosulfate solution equivalent to 25 ml. of standard bromate solution, and

C = milliliters of sodium thiosulfate solution required in the titration.

(e) Blank Determination.—Make a blank determination in accordance with the same procedure as outlined above, and using approximately the same amounts of reagents. Correct the titration results accordingly.

Note 4.—An excess of the 8-hydroxyquinoline reagent should be used. If it is small the result of the determination of magnesia may be low; on the other hand, if large, the result may be high. The following guide may be used:

Approximate Content of Magnesia, percent	*Approximate Amount of Reagent Required, Ml.*
0 to 1.5	10
1.5 to 3.0	15
3.0 to 4.5	20
4.5 to 6.0	25

Note 5.—The precipitate should be filtered within an hour. Prolonged standing may cause high result.

Note 6.—The amount of the standard bromate solution used may be as follows:

Approximate Content of Magnesia, percent	*Amount of Standard Bromate Solution, Ml.*
0 to 1	10
1 to 2	15
2 to 3	20
3 to 4	25
4 to 5	30
5 to 6	35

Section 12 and all subsequent sections to be renumbered.

The ASTM designation of the amended specification to be changed to C77–38*.

Add footnote on page 8–11 to read:

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* Under the standardization procedure of the Society, these specifications are under the jurisdiction of the ASTM Committee C-1 on Cement.

Appendix B

(2) SPECIFICATIONS AND PRINCIPLES OF DESIGN OF PLAIN AND REINFORCED CONCRETE

For Use in Railway Bridges, Buildings and Culverts

A. N. Laird, Chairman, Subcommittee; F. E. Bates, T. L. Condron, Hardy Cross, G. H. Dayett, Theodore Doll, R. Hayes, Meyer Hirschthal, A. C. Irwin, J. E. Kalinka, C. P. Marsh, J. L. Rippey, C. P. Schantz, L. W. Skov, A. W. Smith, Jamison Vawter, W. R. Wilson, H. A. Wistrich.

Isteg Reinforcing Steel

"Isteg" steel reinforcing bars consist of two plain round bars of equal diameter twisted together to a pitch equal to 12½ times the diameter of the component bars in such a way that the length of the twisted unit remains the same as that of the original bars. In the manufacture of "Isteg" bars, the component bars are securely clamped in chucks such that the bars will be stretched and twisted while being rotated to the required pitch. This operation is a cold working process involving two distinct changes in the metal, namely, stretch and torque.

Various tests have been made of this material and reported in the Journal of the American Concrete Institute, the testing reports of Columbia University and elsewhere, which indicate that the yield point and ultimate strength of the steel is increased, accompanied by somewhat higher bond stresses. It is recommended that the reader study the original test reports for a verification of the amount in each case.

Specifications for Composite Columns and Pipe Columns

Specifications for composite columns and pipe columns have been considered further in connection with the progress report of the Joint Committee on Concrete. As a satisfactory conclusion has not been reached, further study of this subject is necessary.

Concrete Bridge Deck Slabs of the Non-Ballast Type

The committee has assembled a considerable volume of information on this subject. Further time is required to analyze the results and check service records.

This report is submitted as information with the recommendation that the subject be continued.

Appendix C

(3) PROGRESS IN THE SCIENCE AND ART OF CONCRETE MANUFACTURE

L. W. Walter, Chairman, Subcommittee; H. F. Bober, Maurice Coburn, T. L. Condron, W. K. Hatt, R. Hayes, Meyer Hirschthal, A. C. Irwin, J. A. Lahmer, C. P. Marsh, W. M. Ray, G. W. Rear, H. H. Temple, J. H. Titus, C. A. Whipple.

Section I

PRESSEDWOOD, PLYWOOD AND SPECIAL FIBROUS MATERIALS FOR FORMS AND FORM LINING

Pressedwood and plywood used for forms and form lining have become popular within the last seven or eight years Not only has the facility with which forms may be constructed with this material contributed toward its popularity, but under many circumstances it has also effected a saving in cost.

Plywood

Plywood used for form work is made ordinarily from Douglas fir and may be had in plies of three, five or seven in standard thickness. Selected logs in appropriate lengths are turned in a giant lathe and sheets are peeled off in almost endless lengths. These sheets are assembled to form the plywood of commerce by gluing them together with water-resistant glue which sets under hydraulic pressure to form a bond of high shearing strength. The plies are alternated with respect to to their grain direction. This arrangement gives the strength in tension of the fibers in two directions as well as the strength in shear across the grain and resists the tendency to warp.

Plywood may be had in increments of $\frac{1}{16}$ in. in total thicknesses, ranging from 0.25 in. to 0.75 in. Various widths are carried in stock and a width up to 48 in. can be obtained. Sheets 24 in. and under are given a base price with a sliding scale in price for widths greater than 24 in.

The weight of three-ply plywood $\frac{3}{8}$ in. thick is about 35 lb. per cu. ft. This material is available throughout the country and can usually be obtained in a number of sizes and thicknesses at local lumber yards.

Pressedwood

Pressedwood, as the name implies, is manufactured by pressing shredded wood together under heavy pressure and at a high temperature. The fibers are thus compressed into sheets of much strength in all directions. In order to minimize the absorption of water the surface of the pressedwood is "tempered" with hot oil.

Thicknesses of pressedwood may be had ranging from $\frac{3}{16}$ in. to $\frac{5}{16}$ in. The standard sizes are 4 ft. by 12 ft. only. Where full size sheets can be used, the edges are so true that joints do not require pointing or filling.

Use of Plywood and Pressedwood for Forms

There is no single use for which these materials are put to the exclusion of other form materials. They are, however, recommended especially for forming surfaces where the appearance is of importance, for forming curved or warped surfaces, and to carry out ornamental and architectural details.

They may be used either as forms or as form lining. When used as forms they are simply attached to studding and are not assisted by sheathing in resisting the pressure of concrete. The thickness required will depend on the spacing of the studding, the consistency of the concrete, the rapidity with which it is placed and the methods of placement. Ordinarily a five-ply plywood, or its equivalent in pressedwood, is used where no sheathing is employed.

Where these materials are used simply as form liners the thickness ordinarily used is three-ply or the equivalent.

Details of Use

Certain details connected with the method of use have an influence on the re-uses that may be obtained and, consequently, upon economy. When not in use, the panels or sheets should be stored or handled in such way as not to cause warping or to produce excessive bending. Care should be exercised in the removal of nails or other fasteners and, where smooth even surfaces are to be obtained with each re-use, the operations of erecting and dismantling must be done in such a way as not to peel, scratch, mar or roughen the surface. The effect of damage to the surfaces done by such accidents can be minimized oftentimes by reversal or by the use of those forms with marred surfaces on the back of walls or in locations where the surface of the concrete will not be seen. The maximum of re-use will be obtained when the forms are constructed in panels with

supporting studding so that it is only necessary to connect or disconnect the studding in order to erect and take down forms. When live steam is used under canvas for heat curing, plywood is oftentimes damaged sufficiently to reduce the ordinary number of repeat uses.

Plywood should be oiled before using to prevent absorption of water which would tend to raise the grain and separate the plies. Pressedwood should be used in a slightly moist condition. This is best accomplished by wetting the sheets on the screen side 12 hours before using.

Plywood used as built-in-place forms should be nailed at about four to six-inch intervals along all four edges and with one nail per square foot for the entire surface with three-penny shingle nails or with small box nails. Smooth joints may be obtained by nailing the edges of the abutting sheets to the same back board; plywood $\frac{5}{16}$ in. thick and heavier may be used without backing and the sheets nailed directly to studs.

Both plywood and pressedwood may be cut with power or hand saws and dressed with a plane to make a close-fitting joint. Joints that are open enough to permit the insertion of a knife blade may be made tight by pointing with patching plaster or quick-hardening cements or compounds.

Obviously, the thinner the form lining of either pressedwood or plywood, the greater the need for supporting it. Backing boards of 1-in. by 4-in. dressed and matched lumber are recommended. They should not be more than six inches wide. These boards should be firmly attached to the studding and in proper alinement to support the form lining.

Economic Considerations

Where plywood or pressedwood is not specified, economic considerations will govern not only the selection of the type of forms but also the materials comprising them. The economic answer will be affected by the number of re-uses that can be expected, whether or not the structure will permit the use of these materials as forms without backing, whether the forms may be made up in panels for easy erection and removal, surface finishing cost and the relative cost f.o.b. the job of these materials as compared with ordinary matched form lumber.

In addition to plywood and pressedwood, transite board, a composition of asbestos fiber and cement, has been successfully used both as a form and as protection for concrete on bridges over railway tracks.

When plywood is used as lining applied to backing in large form panels for repeat usage, there may be some advantage in using a filler strip of lining between the ends of the lining on adjacent panels. When it is necessary to saw off ragged edges of the lining at vertical joints, a filler strip can be inserted to fill the gap.

This report is presented as information with the recommendation that the subject be continued.

Section II

STANDARD PORTLAND CEMENT COMPARED WITH STANDARD HIGH-EARLY-STRENGTH PORTLAND CEMENT

The ASTM specification requirements for the two types of Portland cement differ in two particulars, namely, strength and maximum allowable SO_3.

For Portland cement, the average tensile strength of the standard mortar briquets must be higher than 275 lb. per sq. in. at 7 days and 350 lb. per sq. in. at 28 days, with the further provision that the strength at 28 days shall be higher than at 7 days.

For high-early-strength Portland cement, the tensile strength requirements are 275 lb. per sq. in. at 1 day and 375 lb. per sq. in. at 3 days; also, the 28-day strength shall be higher than the 3-day strength.

No fineness requirement is specified for Portland cement or for high-early-strength Portland cement.

The specific surface of cement expressed in sq. cm. per gram, as now manufactured, generally lies between 2,000 and 2,400 for high-early-strength Portland cement and between 1,600 and 1,800 for normal Portland cement.

The finer grinding of high-early-strength cement requires the addition, subsequent to calcination, of slightly more calcium sulphate (gypsum) to control the setting time and therefore the maximum allowable SO_3 content for high-early-strength Portland cement is established at 2.5 percent as against 2 percent for Portland cement.

In a study of the difference in quality and performance of the two types of cement one must keep in mind the fact that different brands of cement in each type or the product of different mills sold under the same brand may, and ofttimes do, have different charactertistics. It should also be borne in mind that since the first introduction of high-early-strength Portland cement the gap in strength between the two types of cement has been partly closed by reason of the large increase in early strength of normal Portland cement.

Heat of Hydration

The reactions incident to setting and hardening in cement are accompanied by the evolution of heat. The more rapid the hardening, the more rapid will be the evolution of heat and consequently the higher the temperatures attained in a given mass of concrete. For very large masses, where the opportunities for dissipation of heat during the hardening period are limited, the temperature rise in the concrete becomes an important factor and under these conditions the use of high-early-strength cement may be undesirable. The recent development of a cement of moderate heat of hardening has resulted from the general tendency towards more rapid hardening and higher early strength in normal Portland cement.

As an aid in choosing between the two types of cement for a particular project the following information and suggestions are offered.

Durability

Laboratory tests of specimens of concrete and mortar subjected to alternate freezing and thawing have shown that when each type of cement is cured to develop a large proportion of its total potential strength there is little difference between the two types. However, when specimens are so tested at early ages, the more rapid development of strength, characteristic of the high-early-strength cement, is reflected in an increased resistance to freezing and thawing.

In the matter of resistance to the action of alkali soils or sulfate ground waters, there is, in general, no difference between these two types of cement. The question is not one of type of cement, but rather one of composition. Recent studies have generally shown that resistance to sulfate action is increased as the percentage of tricalcium aluminate in the cement is reduced.

Early Strength

For emergency needs, where early strength and speed are the essentials, high-early-strength Portland cement is preferable. For non-emergency work, the choice between the two types of cement may depend upon job conditions, type of structure, temperature and

other variables. Specifically, some of the conditions that prompt consideration of the use of high-early-strength cement are the following:

1. When completion of work in the shortest possible time is necessary.
2. Where economy may result from use of high-early-strength cement on account of:
   (a) Early form removal and re-use.
   (b) Early occupancy or use of the structure or work.
   (c) Restricted areas for handling and storing construction materials or making and storing precast units.
   (d) Repairs to structures in service.
   (e) Shortening the necessary heat curing period in cold weather.

Where economy of construction is the aim, so many factors may enter into the choice between types of cement as to make the selection difficult. If concrete is designed for a given strength at the early testing periods the same strength may be approximated by using more normal Portland cement than would be required if high-early-strength cement were used. If success is attained in matching strength at the early testing period by using different amounts of the two types of cement, it may be expected that the normal Portland cement will produce higher ultimate strength. If good workability is a prime essential in placing the concrete the advantage may lie with normal Portland cement used in greater quantity than would be necessary to produce like strength with high-early-strength cement. When either type is permitted under a specification based on arbitrary proportions, the choice may depend upon the type of structure, the time of year or other conditions peculiar to the job.

Your committee feels that the choice between the two types of cement in the interest of ultimate economy can be more easily made from the calculation of conditions known or anticipated as applicable to a particular job than by offering general statements when conditions involved are indeterminate.

This report is submitted as information with the recommendation that the subject be continued.

Appendix D

(5) SPECIFICATIONS FOR FOUNDATIONS

Jamison Vawter, Chairman, Subcommittee; F. E. Bates, H. F. Bober, Hardy Cross, G. H. Dayett, G. F. Eberly, L. H. Hornsby, O. V. Parsons, G. W. Rear, G. R. Smiley, C. A. Whipple, W. R. Wilson, J. J. Yates.

The committee presents below, Specifications for Pile Foundations, of which Article I —Scope, Article II—Purpose and Necessity, Article III—Design, Article IV—Allowable Load on Piles, and Article V—Loading Test, are recommended for adoption and publication in the Manual. The remaining articles, VI—Types of Piles, VII—Driving, and VIII—Spacing of Piles, are submitted as information.

SPECIFICATIONS FOR PILE FOUNDATIONS

I SCOPE

These specifications cover the investigation, design and construction of pile foundations.

II PURPOSE AND NECESSITY

Pile foundations may be used when the bearing power of the soil is insufficient to carry the superimposed loads or where the possibility of scour may cause a change in the underlying foundation condition.

Depending upon subsoil conditions, piles consolidate the soil and transfer the load to less firm substrata by skin friction, or act as columns to carry the supported load to the hard substrata.

III DESIGN

1. Loads

The pile foundation shall be designed for that combination of the following forces which produce the maximum load.

Primary

(a) Dead
(b) Live
(c) Centrifugal force
(d) Earth pressure
(e) Buoyancy

Secondary

(f) Wind and other lateral forces
(g) Longitudinal forces

2. Increased Load on Piles

When the pile foundations are designed for both primary and secondary forces, as defined above, the allowable load on the piles may be increased by 25 percent, but the number of piles shall not be less than is required for primary forces alone.

3. Eccentricity of Loads

The maximum pile load under eccentric loads shall not exceed the allowable load.

4. Bending in Piles

When piles are not supported laterally by the material through which they are driven, or when driven in stream beds where scour occurs, the sections of the piles shall be proportioned for the combined direct load and bending produced by the specified loads.

5. Uplift on Piles

When piles are subjected to uplift and sufficient bond exists between the pile and the superimposed structure, the uplift may be considered in the design of the pile foundation.

IV ALLOWABLE LOAD ON PILES

1. Test borings or pits shall be made to determine the character of the material through which the pile is to be driven. Exploration should be made to a sufficient depth, below the foot of the piles, to adequately determine the characteristics of the underlying materials.

2. For the purpose of determining the load distributed to the underlying stratum, piles and groups of piles shall be assumed to transfer their loads to the supporting materials by spreading the load uniformly at an angle of 60 degrees with the horizontal, starting at the perimeter of the piles at the top of a satisfactory bearing stratum in which they are embedded, but the area considered as supporting the load shall not extend beyond the intersection of the 60-degree planes of adjacent piles or pile groups. The underlying stratum shall be able to support the load thus carried to it.

3. The allowable load per pile shall be determined by a loading test, preferably of a group of piles. The loading test shall be made in accordance with the provisions of Section V.

4. The allowable pile load shall be not more than one-half of the load which caused a settlement of the test piles of ¼ inch, which settlement remained constant for 48 hours, but the load on the materials below the foot of the pile, determined as per Section IV 2, shall not exceed the allowable load on that material, nor exceed the allowable compressive stress in the pile material.

5. When the test borings show conclusively that the bottoms of the piles will bear on solid rock, the allowable bearing pressure of the pile on the rock, unless limited by other determined pile capacity, shall govern the allowable load.

6. A complete record of the penetration of the test piles, the type of hammer, number of blows per minute, type, size and elevation of foot of piles shall be kept. If the test piles develop sufficient capacity, the remainder of the piles shall have the same penetration per blow, for the last foot of penetration, using the same hammer at the same speed.

7. In determining the working loads from the loading test results, due consideration should be given to:

(a) The difference between the supporting capacity of a single pile and a group of piles.

(b) The capacity of the underlying strata to support the load of the pile group.

(c) The effect of driving additional piles and the effect of their loads on adjacent structures.

(d) Possibility of scour and its effect.

V LOADING TEST

1. Piles which have been jetted shall be finally driven to the required penetration and the records as per Section IV 6, taken before the test is made.

2. Shattered, broomed or otherwise damaged pile heads, shall be cut back to sound material before the test is made.

3. Test loads shall be applied by direct weight or by hydraulic jack pressure that is automatically maintained constantly. Except in the case of rock bearing, not less than 24 hours shall elapse between completion of driving and application of initial test load.

4. The piles to be tested shall be loaded to at least twice the proposed working load. The load shall be applied in increments of not over 10,000 pounds per pile and at least 4 hours shall elapse between the addition of successive increments.

5. Settlement readings accurate to $\frac{1}{32}$ inch, shall be taken and recorded immediately before and after each increment of load is added. These readings shall be referred to a bench mark at sufficient distance from the piles to be not affected by them.

6. In determining the settlement of the piles, proper deductions shall be made for the elastic compression of the piles under the test load.

VI TYPES OF PILES

(A) Timber

Timber piles shall conform to the "Specifications for Wood Piles" pages 7–1 to 7–4 of the Manual of the American Railway Engineering Association.

(B) Concrete

1. Pre-cast

(a) *Manufacture.* The manufacture of pre-cast concrete piles shall conform to the "Specifications for Making Pre-molded Concrete Piles", page 8–87 of the Manual of the American Railway Engineering Association.

(b) *Design.* Pre-cast piles shall be of an approved design.

Piles of constant cross-section shall have a least diameter or lateral dimension of 14 inches for piles up to 35 feet in length and not less than 16 inches for lengths over 35 feet and not over 50 feet. Piles over 50 feet in length shall be of a size and design approved by the Engineer. The pile may be pointed as the Engineer directs.

Piles with a uniform taper shall have a minimum lateral dimension of not less than 8 inches at the point and an average diameter of not less than 12 inches for lengths not over 40 feet. Piles over 40 feet shall have a minimum taper of 1 inch in 8 feet and a lateral dimension at the point of not less than 10 inches.

The reinforcement shall consist of longitudinal bars, supported by lateral reinforcement in the form of hoops or spirals. The longitudinal reinforcement shall be designed for handling stresses and shall normally consist of 8 bars, uniformly spaced, and not less than ½ inch nor more than 1 inch in size. The cross-sectional area of the longitudinal reinforcement shall be not less than 1 percent nor more than 4 percent of the average gross cross-sectional area of the pile. The lateral reinforcement shall consist of not less than No. 7 steel wire, spaced not more than 8 inches center to center throughout the length of the pile, except that for not less than 2 feet at each end the spacing shall not exceed 3 inches center to center. The reinforcement shall be placed with a cover of not less than 1½ inches and greater cover as conditions require. Steel reinforcement shall conform to the AREA Specifications for Steel Reinforcement as given on pages 8–2 and 8–3 of the Manual.

(c) *Cut-off.* Pre-cast piles shall be driven to or cut off within 2 inches of the elevation shown on plans, but in all cases the cut-off shall be below any indication of fracture. If piles are cut off or driven below the required elevation, the pile shall be built up to the cut-off line in a manner satisfactory to the Engineer.

2. Cast-In-Place

(a) *Types.* Cast-in-place piles may be tapered piles in metal cases, cylindrical piles in metal cases or uncased cylindrical piles. Where steel cylindrical shells are used, $\frac{5}{16}$ inches thick or more, they shall be classed as steel piles and are specified under Section VI(C)2.

(b) *Tapered Piles.* Tapered piles shall be not less than 8 inches in diameter at the tip and the diameter shall be uniformly tapered at the rate of 1 inch in 4 feet for shells up to 40 feet in length, and not less than 1 inch in 8 feet for shells over 40 feet in length. Piles between 40 feet and 56 feet in length shall have a minimum average diameter of 12 inches. Piles over 56 feet in length shall be of a size and design approved by the Engineer. When driving without a mandrel the tips shall have a steel driving point welded to the shell. The shells shall be in one integral piece or adequately spliced. The large end shall be thoroughly reinforced to withstand driving.

(c) *Cylindrical Piles.* Piles of constant cross-section shall have a minimum diameter of 14 inches for lengths up to 35 feet, and 16 inches for lengths over 35 feet and not over 50 feet. Piles over 50 feet in length shall be of a size and design approved by the Engineer.

Piles with shells pulled may be used where specified. Where shells are to be pulled they shall be equipped with shoes of approved design.

(d) *Metal Casings.* The metal casings or shells shall be formed of basic open hearth steel. The metal of shells driven with a mandrel shall have a thickness of not less than No. 18 B.W.G. The metal of shells which are driven directly shall have a thickness of not less than No. 7 B.W.G. except where fluted shells are used the minimum thickness may be No. 11 B.W.G. In all cases the thickness shall be sufficient to withstand the driving without failure.

(e) *Placing Concrete.* Shells must be inspected and approved by the Engineer immediately before any concrete is placed. They must be clean and free of any water or foreign matter. They must be undistorted and of the specified dimensions. The concrete shall be Class 2500 and the placing shall be continuous from tip to cut-off elevation. Where shells are pulled the concrete shall be placed during pulling. Segregation in depositing shall not be permitted.

Reinforcement shall not be used unless especially specified.

No cast-in-place pile shall be filled with concrete until all adjacent piles within a radius of 4½ times the average pile diameter, or not less than 5 feet, have been driven to the required resistance.

After a shell has been filled with concrete, no shell or pile shall be driven within 15 feet thereof until at least 4 days have elapsed.

(f) *Allowable Load.* The allowable load per pile shall be determined as specified in Section IV but shall not exceed 600 pounds per square inch for the area at the average diameter of tapered piles, 400 pounds per square inch for cased cylindrical piles and 300 pounds per square inch for uncased cylindrical piles.

(C) Steel

Material. All steel used for piles shall conform to the AREA Specifications for Structural Steel.

The concrete used in pipe piles shall conform to the AREA Specifications for Concrete, Plain and Reinforced. Concrete shall be Class 2500.

1. H-Sections

(a) *Size.* The minimum depth of section shall be 8 inches. The minimum thickness of the metal shall be ⅜ inch.

(b) *Splicing.* Full length piles shall be used where practicable, but if splices cannot be avoided, an approved method of splicing shall be used. Piles shall not be spliced except by permission of the Engineer.

(c) *Capping.* Tops of piles encased in concrete shall be provided with steel bearing plates suitably fastened to the piles so as to avoid displacement and to provide even bearing on the pile. The bearing plate shall be of such size that the bearing on the footing concrete shall not exceed 1,000 pounds per square inch. Tops of piles shall project not less than 12 inches into the concrete.

Piles which extend several feet into a concrete footing may be bonded to the concrete by means of a mat of reinforcing bars running through holes in the piles.

(d) *Protective Encasement.* Piles shall be protected from corrosion by means of concrete encasement extending at least one foot above ground or normal water line and three feet below the ground or minimum water line. The minimum concrete cover shall be 3 inches.

(e) *Allowable Load.* The allowable load per pile shall be determined as specified in Section IV. The unit stress on H-Section piles shall not exceed 10,000 pounds per square inch for Primary Loads. Due allowance shall be made for any bending or column action as specified in section III 4.

2. Pipe Piles (Steel Pipes Filled with Concrete)

(a) *Size.* Pipe shall have an inside diameter of 10 inches or more and a thickness of not less than $\frac{3}{8}$ inch, except that a thickness of $\frac{5}{16}$ inch may be used on 10 inch and 12 inch pipe.

(b) *Splicing.* Splicing shall be of an approved design. Ends of pipes shall be faced perpendicular to the axis and held together at splices by sleeves. Sleeves should be a tight driving fit on or in the pipe and should extend a distance equal to the diameter of the pipe, above and below the splice. Means should be provided for prevention of movement of the sleeve during driving of the pile.

(c) *Capping.* Tops of piles shall project not less than 12 inches into the foundation concrete.

(d) *Placing Concrete.* Inside of pipes must be cleaned of any foreign matter before concrete is placed. The placing of concrete shall be continuous from tip to cut-off elevation. Segregation in depositing shall not be permitted.

No pipe pile shall be filled with concrete until all adjacent piles within a radius of $4\frac{1}{2}$ times the average pile diameter, or not less than 5 feet, have been driven to the required resistance.

After a pipe has been filled with concrete, no pipe or pile shall be driven within 15 feet thereof until at least 4 days have elapsed.

(e) *Allowable Load.* The allowable load per pile shall be determined as specified in Section IV. The allowable load on the pile shall not exceed 400 pounds per square inch on the concrete and 6000 pounds per square inch on the steel, provided that in computing the effective area of the steel the outer $\frac{1}{8}$ inch of thickness shall be deducted from the thickness of the pipe; except the total load carried by the steel shall not exceed one-half the total load on the pile. If the length of a pile is more than 40 diameters, the limit of load specified in this paragraph shall be reduced by one percent for each diameter in length in excess of 40 diameters. If splices below the upper section are closer than 20 feet, the allowable load on the pile shall be reduced 5 percent for each splice in excess of the number required for 20 foot spacing. No interior steel reinforcement shall be used.

(D) Composite Piles

Composite piles shall consist of a combination of any two types of piles covered in this specification. The minimum dimensions of each part shall be the same as specified for piles of its type. The allowable load shall be limited by the strength of the weaker type. The joint between the two types shall be such as to prevent their separation, maintain alignment and support the load. All details of the joint, method of driving and the design of composite piles shall be subject to the approval of the Engineer.

VII DRIVING

1. Piles shall be driven with the heaviest hammer that in the judgment of the Engineer can be used to secure maximum penetration without damage to the pile.

2. Timber and concrete piles shall be protected with an approved cushion cap while being driven.

3. Followers, if used, shall be of steel or iron with a suitable socket to protect the head of the pile. Damaged portions of the pile head shall be removed, and the head properly prepared before the follower is placed.

4. The excavation for pile foundations, where practicable, shall be made to or below the elevation of the cut-off of the piles before the piles are driven.

5. Piles may be jetted, where conditions warrant, but they should be driven to the final penetration as determined by the test piles.

6. Any pile so injured in driving or handling as to impair its structural integrity as a pile under the conditions of use shall be replaced by a new pile, or the injured part replaced by splicing or other remedial measures adopted—all as directed by the Engineer. Unless otherwise called for on the plans, piles shall be driven as nearly as possibe in a plumb position. Any pile so out of line or plumb as to impair its usefulness shall be pulled and redriven or an additional pile driven, as required by the Engineer.

7. On sloping ground or under difficult conditions of driving the pile shall be started in a hole, or guiding templates or other means provided if necessary to insure driving in proper location and line.

VIII SPACING OF PILES

Piles shall be spaced so as to distribute their loads to the supporting materials according to Section IV 2. The minimum center to center spacing shall be not less than 2½ times the butt diameter or side, or 2½ times the depth of steel H-sections. Where practical, piles should be so spaced as to equalize their loads.

Appendix E

(6) METHODS AND PRACTICES OF LINING AND RELINING TUNNELS

I. L. Pyle, Chairman, Subcommittee; G. E. Boyd, Maurice Coburn, G. F. Eberly, O. V. Parsons, G. R. Smiley, J. H. Titus

Your committee reports progress on the subject of Methods and Practices of Lining and Relining Tunnels and presents the following as information. This preliminary report sets forth the various types of tunnel lining that will be considered in subsequent reports on lining and relining tunnels.

Brick

While brick was one of the earliest materials used in the lining of tunnels, its use has been almost discontinued in Canada and the United States. The English roads still use brick exclusively while the French use brick and stone, brick in the arch and stone in the side walls. The first cost of brick lining is considerably more than concrete. Great care must be exercised to secure good fit of joints, and sufficient number of headers, and to insure that the joints are carefully broken. It is particularly important that the proper amount and quality of mortar be used, not too much nor too little. Arch centers

should be slacked—not struck—immediately after keying so that mortar may harden under slight pressure.

Vitrified bricks, having a compressive strength of 6,000 lb. per sq. in. and an absorption not to exceed 3 percent of their weight in a 24 hour period, meet the strength requirements of most tunnel structures and provide a material that is highly resistant to the sulphuric gases and soot in railway tunnels through which coal burning locomotives are operated. The mortar joints are the principal points of attack for engine blasts and gases; and, unless the courses of brick are carefully bonded, these agencies will cause failure of the lining by permitting bricks to become loose and fall out. Restoration of joints can often be made by pointing, or the joints can be cleaned by sand blasting and washing and shotcrete used for replacing mortar.

In some of the earliest work done in this country, hand-made bricks were found to be superior to machine made. This was due to their coarser, or rougher, texture with consequently better bonding.

While the first cost is greater, the maintenance cost will be small and the cost per service life year may be no greater than for other types of lining, as evidenced by the condition of brick linings that are now from 40 to 50 years old. Brick lining will sustain considerable damage before suffering complete failure. It will not resist side pressure as well as some other type of lining.

Stone

The use of stone for railway tunnel linings has been about discontinued, due primarily to the high initial cost and the scarcity of skilled stone cutters. A relatively small amount of stone was used in arches. Its principal use was in the sidewalls of tunnels where brick was used in the arches. This method is still being used by French roads.

Concrete

The use of concrete, plain and reinforced, for the lining of railway tunnels is almost universal. This is due to its lower initial cost, adaptability to unusual construction conditions and low cost per service-life year. The use of portable, steel forms and pumps for placing concrete has reduced the cost to some extent for this class of tunnel lining.

Plain concrete is to be preferred to reinforced concrete due to its lower initial cost and, also, because it can be more efficiently placed and worked in the forms. When seepage finds its way into the lining where reinforcement is used, corrosion of the metal will probably occur with consequent cracking of the concrete. If reinforcing is necessary because of unusual pressures, the thickness of the concrete should be increased to provide for the placing of the reinforcing so as to perform its function properly.

In some of the early concrete lined tunnels, through which coal burning locomotives are operated, some deterioration has taken place in the arches. This is probably due to the character of concrete used and the small tunnel section. The damage was caused by sulphuric acid found in gases and soot and also by the blast from locomotive stacks. This condition has been materially improved by the use of denser concrete and larger tunnel sections. Seepage water in wet tunnels can be controlled better when plain concrete is used than with some other types of lining.

Shotcrete

Another type of concrete lining is known as shotcrete, plain and reinforced. This material is placed by a cement gun. The material is used very efficiently in covering natural rock in tunnels to prevent the disintegration, loosening and falling of rock. Shotcrete has also been used for encasing steel liner plates, in which case the rock packing in the rear of the liner plates was thoroughly grouted to refusal before applying the shotcrete.

Shotcrete, due to its density, is highly resistant to sulphuric acid attack. It should, however, be thoroughly cured by wetting so as to develop its full resistant qualities and prevent small hair cracks. It can also be used successfully for repairing concrete and brick linings.

This report is submitted as information with the recommendation that the subject be continued.

Appendix F

(7) SPECIFICATIONS FOR PLACING CONCRETE BY PUMPING

I. L. Pyle, Chairman, Subcommittee; G. E. Boyd, W. K. Hatt, A. C. Irwin, L. W. Walter.

Scope

1. These specifications cover the general requirements for transporting and placing concrete by pumping, whether mechanically or by the use of compressed air.

Equipment

2. The pump and all appurtenances shall be so designed and arranged that the specified concrete can be transported and placed in the forms without segregation.

3. If piston type of pump is used, it shall be capable of developing a working pressure of at least 300 pounds per square inch and the pipe line and fittings shall be designed to withstand twice the working pressure.

4. If the pump or machine is of the type in which delivery of concrete through the pipe is effected directly by air, there shall be available a working pressure of 120 pounds of air per square inch. A constant air pressure shall be maintained; and, in some instances, a reservoir shall be installed in the air line so as to secure a continuous flow. A regulating valve shall be installed in the air line so as to control the pressure for variations in distance and height of placement.

Operation

5. Where concrete is conveyed and placed by mechanically applied pressure (piston type of pump), the operation of the pump shall be such that a stream of concrete without air pockets is produced.

6. Where it is necessary to lay the pipe on a down grade, a reducer shall be placed at the discharge end of the pipe so as to provide a choke and thus provide a continuous flow of concrete.

7. When the type of pump is such that it discharges the concrete in small batches, or by "belching", a baffle box shall be provided into which the concrete shall be discharged. This box should preferably be of metal, about two feet square, with open sides so as to permit the concrete to flow into the forms at right angles to line of discharge.

8. The pipe shall be not less than 6 inches nor more than 8 inches outside diameter, and the line shall be laid with as few bends as possible. When changes in direction are necessary they should be made with bends of 45 degrees or less. If 90-degree bends are permitted they shall be long-radius bends.

9. The maximum distance of delivery of concrete by pumping shall be 1,000 feet horizontally and 100 feet vertically, unless otherwise specifically permitted by the en-

gineer. (A 90-degree bend is figured as equivalent to 40 feet of horizontal piping, a 45-degree bend is equivalent to 20 feet and a 22½-degree bend is equivalent to 10 feet).

10. When pumping is completed, the concrete remaining in the pipe line, if it is to be used, shall be ejected in such a manner that there will be no contamination of the concrete or separation of the ingredients. The pipe line and equipment must then be thoroughly cleaned. The pipe line can be cleaned by either water or air. If water is used, a pump shall be provided with a capacity of at least 80 gallons per minute and capable of developing a pressure of 400 pounds per square inch. Cleaning of the pipe can also be accomplished by the use of a "go-devil" which is propelled through the line by water or air pressure. (The "go-devil" is a dumb-bell shaped piece with a cup rubber on each end. The cups are turned toward the liquid, or air, and the seal is the same as in a simple plunger pump.) If water is used, it must be discharged outside of the forms.

Mixing and Proportions

11. The proportions of the ingredients and the mixing of the concrete shall be in accordance with the AREA specifications for Portland Cement Concrete, Plain and Reinforced, and no deviation in the water ratio or material characteristics will be permitted. (Best results will be obtained by using coarse aggregate not exceeding 2½ inches and concrete with a slump of not less than 3 inches nor more than 6 inches). Concrete should not be allowed to stand in the pipe line longer than 45 minutes for average temperature.

Duplicate Equipment

12. On important work duplicate pumping equipment and additional pipe shall be provided so as to prevent delay due to breakdown of equipment.

Recommendation

The committee recommends that these specifications be approved for inclusion in the Manual and that the subject be continued.

Appendix G

(10) INVESTIGATION OF THE MERITS OF THE VACUUM METHOD OF TREATMENT OF CONCRETE AFTER PLACEMENT

G. E. Robinson, Chairman, Subcommittee; C. P. Marsh, I. L. Pyle, F. B. Robins.

The merits of the vacuum method of the treatment of concrete have been investigated by your committee to the extent of studying the available literature, visiting the laboratory of a sponsor to witness a demonstration, and holding a member ready to visit a field demonstration upon notification. However, the committee has received no notice of such a demonstration in a period of 18 months.

The vacuum process of treating freshly poured concrete aims to remove, as far as possible, all water not needed for chemical reactions. The method of application employed by one company is as follows: A mat is used which is composed of a backing of thin metal, a layer of expanded metal, a face of specially treated canvas, the whole surrounded by a strip of rubber two inches wide whose function is to seal the edge. A

suction outlet is provided in the backing for about every ten square feet of area. The hose from the compressor ends in a soft rubber suction cup which fits over the suction outlet. The expanded metal provides a ⅛-in. waterway through which the water from all parts of the surfaces can reach the outlet.

These mats can be made in any convenient size, usually controlled by the weight which is about 100 lb. for a mat 3 ft. by 10 ft. A vacuum of 23 to 26 in. is applied, which it is claimed will remove about 40 percent of the water from a 6-gal. mix in 10 to 20 min., depending on the thickness of the section. The action of the vacuum produces a pressure of about 1,500 lb. per sq. ft. on the surface of the concrete. The present development of the equipment limits its use to sections not over 36 in. thick where vacuum can be applied to both sides.

At the laboratory your committee saw a mat used which was backed with celluloid so that the course of the water could be observed. The water comes from all parts of the surface in drops which, as they dodge their way to the outlet through the expanded metal, give the appearance of a dense army of ants hurrying to a feast. In the hose, which had a glass suction, the flow was a steady stream of clear water, and this water, when visually examined, showed no cement. A small vertical slab three feet by four feet by three inches was cast of concrete of about five-inch slump, vacuum was applied for ten minutes and the forms immediately removed. The weight of a man standing on the edge of the slab left no imprint, and the concrete was of about the right hardness for surface finishing.

The committee has been furnished with the results of some preliminary tests made by a neutral laboratory on 2-in. by 5-in. by 22-in. beams. Compared to wet cast units molded without vibration, the vacuum processed specimens showed:

20 percent less volume change.
30 percent increase in strength.
40 percent decrease in absorption.

In a test on vibrated specimens of a 5-gal. mix subjected to a 4-in. vacuum for 4 min., followed by 7½-in. to 8 in. for 6 min., 1 gal. of water per sack of cement was recovered.

The sponsors claim the following advantages for their process:

Volume change materially reduced.

Strength increase about 50 percent.

Absorption decrease about 30 percent.

Large increase in bond when resurfacing old concrete due to the utilization of atmospheric pressure.

Forms reduced to skeletons. In vertical walls, the hydraulic pressure is reduced to the width of one mat, i.e., 15 in. to 24 in.

Construction time greatly reduced due to immediate stripping.

Supporting evidence for the last claim was the completion, and surface finishing of the exterior walls of a 27-ft. by 37-ft. bungalow in one working day.

Reliable cost figures are not available at the present time on which to base estimates or select the type or minimum size job where this process could be used economically.

This report is presented as information with the recommendation that the subject be continued.

Appendix H

(13) SPECIFICATIONS FOR CONCRETE CULVERT PIPE

Theodore Doll, Chairman, Subcommittee; J. A. Lahmer, A. N. Laird, J. L. Rippey, F. B. Robins, G. E. Robinson, Jamison Vawter, H. A. Wistrich.

The Specifications for Reinforced Concrete Culvert Pipe, ASTM serial designation C–76–37, which have been approved by the AREA, contain design tables which give the minimum amount of reinforcement and minimum shell thickness permitted, together with the minimum test loads allowed, for each size of pipe. The data in these design tables are entirely empirical, being based on numerous tests of pipe, and the specifications are intended to be used only when the pipe is manufactured and tested as required by the specifications.

While the use of concrete culvert pipe that is not manufactured and tested in accordance with ASTM Specifications C–76–37 should be avoided, conditions sometimes dictate the use of a small amount of pipe that is made locally and cannot be tested without undue expense. Under such circumstances the engineer is entitled to be provided with some method of determining whether the pipe in question will carry the proposed loads safely.

Such pipe will be suitable to carry the assumed loads if it meets the following requirements:

1. The bending moments and thrusts shall be determined by the theory of elasticity. The coefficients and formulas given in the table may be used, if applicable. The dead load of the pipe should be included. The coefficients in the table will give satisfactory results for elliptical as well as circular pipe, by using the vertical diameter with horizontal loads and the horizontal diameter with vertical loads.

2. The shell thickness shall be not less than that required by ASTM Specifications C76–37.

3. The stresses in the concrete and in the steel reinforcement shall be computed by means of the standard formulas for rectangular beams.

4. The stresses computed as described in (1) and (3) shall not exceed the values permitted by the AREA Specifications for Portland Cement Concrete, Plain and Reinforced.

5. The requirements of the following sections of ASTM Specifications C76–37 shall be met: Sections 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16, 29, 30, 33, and 34. In addition, the concrete shall meet the requirements of the AREA Specifications for Portland Cement Concrete, Plain and Reinforced, and concrete pipe shall not be installed until test cylinders indicate that the concrete has attained the required strength.

Concrete pipe ought to be manufactured under rigid inspection, and the foregoing recommendations are not intended to be applied to pipe that is manufactured and tested by a reputable manufacturer in accordance with ASTM Specifications C76–37, but only to pipe that is manufactured locally, in a small plant, and not tested.

Recommendations

The foregoing is the same, with slight editorial corrections, as presented last year, and is now submitted for adoption and printing in the Manual. It is recommended that the subject be continued.

Load	Moment at Crown	Moment at Bottom	Mom at End of Horiz. Dia.	Thrust at Crown	Thrust at Bottom	Thrust at Horizont. Diameter
(1)	+0.159	+0.159	-0.091	0	0	+0.5
Concentrated Load Top & Bottom.						
(2)	+0.147	+0.075	-0.077	+0.053	-0.053	+0.5
(3)	+0.0625	+0.0625	-0.0625	0	0	+0.5
Uniform Load Top & Bottom.						
(4)	+0.096	+0.153	-0.084	-0.0265	+0.0265	+0.5
(5)	-0.052	-0.073	+0.0625	+0.3125	+0.6875	0
Lateral Pressure without Surcharge.						
(6)	+0.090	+0.090	-0.077	0	0	+0.5
Triangular Load Top & Bottom.						
(7)	+0.084	+0.068	-0.070	+0.0265	-0.0265	+0.5

Moment = C·W·D

Thrust = C·W

W = Total Load on One Half of Pipe; i.e, on left or right half of Case 5, & on upper or lower half of Cases 1, 2, 3, 4, 6 & 7.

D = Diameter of Pipe.

TABLE OF COEFFICIENTS FOR COMPUTING MOMENTS AND THRUSTS IN CULVERT PIPE

Appendix I

(14) RECENT DISCUSSIONS OF THE PRESTRESSING OF REINFORCED CONCRETE

Maurice Coburn, Chairman, Subcommittee; G. E. Boyd, Hardy Cross, A. C. Irwin, J. E. Kalinka, J. F. Leonard, W. M. Ray, A. W. Smith, Jamison Vawter.

For some years European engineers have been actively interested in various means for reducing the tension in reinforced concrete, the most promising of which seems to be the prestressing of the reinforcement. The undesirable tensile stresses may be the result of dead or live load or of volume changes, due to shrinkage, plastic flow or temperature. The following discussion is gathered from various sources.

The term "prestressing" is applied to several operations, but in general, tension is induced in the reinforcement, either before casting, by bracing the bars against form work; or after casting by bracing the bars against the already hardened concrete. In the latter case the rods to be stressed are either left outside of the concrete altogether and imbedded after stressing, or, the bars are coated to prevent bond, and tightened after the concrete has hardened. There is a scheme to get a pull in the steel by heating it electrically until the concrete has hardened, but that would not seem to be good for the quality of the adjacent concrete and it might not provide enough stress.

Purposes

Principally, prestressing serves two main purposes. Where a structure is in tension it furnishes a means to transfer tension from the concrete into the steel. The best results are had where the prestress is sufficient to keep the concrete in compression in spite of any changes in conditions due to load, plastic flow, etc. Where a structure is in compression, as in columns, and the concrete has a tendency gradually to unload compression to the steel, prestressing is expected to be of value, as it will tend to counteract the excess of compression in the reinforcement by increasing the share of the load finally carried by the concrete. Where a member is subjected to a combination of compressive and tensile stresses, prestressing will not only offer the previously cited advantages but, also, where the steel is not imbedded in the concrete until after casting, will permit control of the deflection of the structure in any desired degree, and make it possible to facilitate decentering by relieving the load on the form work.

Advantages Claimed

It is expected that, since the prestressing permits a better distribution of ultimate stresses in the concrete and a reduction of the required cross-sectional area for banding, it should offer a considerable saving in material, of particular value in reducing the dead load and increasing possible length of spans. It is also expected that the greater freedom from cracks and the consequent increased durability of the concrete will be an important advantage. The use of reinforcing steel with a high yield point seems to be essential on account of the need of counteracting plastic flow, which demands either a high amount of prestress, or, where the design permits, a repetition of rod tightening during the first few months when plastic flow is at its height. One quoted instance had an original prestress of 78,000 lb. per sq. in. which, after the loading of the concrete, was reduced to 57,000 lb. per sq. in. In Europe its use for precast products has been quite extended and for pipe, poles, piling, precast beams, etc. its value has apparently been clearly established.

Prestressing has made possible the construction of large span arches and girders in concrete. Hangars with spans well over 300 ft. and girder bridges with spans of over

400 ft. have been built in Germany, Switzerland, etc., by the method of Dischinger-Rinsterwalder, which leaves the tensile steel exposed, making a structure like a trussed beam. The rods are strained with hydraulic jacks during and after decentering.

The practical value of prestressing for field construction will depend largely on efficient and practical means of inducing the desired stresses and holding them as long as necessary.

Current Literature

Although prestressing of arches by this method was applied in America on two halls of 110-ft. span during 1937, prestressing here has been used mainly on circular reservoirs. Purdue University has made some tests, not all of which have been reported on. In the Engineering News-Record of September 23, 1934, Dr. W. K. Hatt presented the results of tests on prestressed concrete beams, and in the February 21, 1935 issue of the same journal, Professor Crepps gave results on concrete pipe which were published also in Bulletin 46 of the university. The steel in these pipe tests was coated so that there was no bond with the concrete.

Probably the most important work on the problem has been done by E. Freysinnet in France. A. J. Boase of the Portland Cement Association, in his "Notes on Inspection of Structures in Europe", which appeared in the Journal of the American Concrete Institute for May–June, 1937, describes the work of Freysinnet at the Marine station at Harve harbor. He says that Freysinnet refers to his development as an entirely new material which he calls "treated concrete", and directs attention to the latter's book Une Revolution dans les Technique du Beton, Paris, 1936.

Freysinnet has also done some interesting work in connection with heat treatment and has developed methods of putting concrete members in compression as they harden, using hydraulic jacks or a rubber diaphragm. This method, with the use of jacks, has been applied to the ribs of long arch spans, in this country on the Rouge River bridge (Engineering News-Record, November 26, 1931). Recently the idea, with a pneumatic diaphragm, was applied to some experimental work by the Missouri State Highway department, avoiding intermediate cracking in 40-ft. slabs. This was explained in Highway Abstracts for February, 1938, and reviewed in the Journal of the Concrete Institute for March–April, 1938, page 535.

The article by Mr. Boase also covers details of the design of an arch for a span of 529 ft. over the River Guyon in France where this method was used by Freysinnet.

"Current Reviews" of the Concrete Institute for March–April, 1938, page 531, contains a review by Inge Lyse of a paper presented by Karl Lenk before the German Concrete Institute convention in March, 1937, on prestressing, that describes some experiences in its development.

"Current Reviews" of the Journal of the Concrete Institute for September, 1937, contains a review by A. U. Theuer of an article by Karl Lenk in Beton u Eisen for May 20, 1937, in which fundamentals of the method are discussed.

In the Review of Foreign Literature in Rock Products, September, 1936, F. O. Anderegg gives abstracts from a paper, presented before a joint meeting in London of the Institute of Structural Engineers and the Societe des Ingenieurs of France, by T. J. Gueritte, an associate of Freysinnet. In the December, 1936, issue of the same journal, Anderegg reviews a paper in Beton u Eisen by K. W. Mautner. These two articles give interesting information on the subject.

"Current Reviews" in the Journal of the Concrete Institute for December, 1937, contains an abstract by A. U. Theuer of a description of a prestressed tunnel lining by Wayss and Freytag that was published in Beton u Eisen for September, 1937.

What is probably the most complete discussion of the subject in this country is given in a 25-page paper by Ivan A. Rosov, assistant engineer of the New York Tunnel Authority, that appeared in the Proceedings of the American Society of Civil Engineers for September, 1937. He gives historical data, valuable references and a mathematical discussion of the application to bridges. This paper provoked some interesting discussion part of which disagrees frankly with some of Mr. Rosov's statements. This discussion was published in ASCE Proceedings for November and December, 1937, and April, 1938.

REPORT OF COMMITTEE 11—RECORDS AND ACCOUNTS

C. A. Knowles, *Chairman;*
Anton Anderson,
D. L. Avery,
F. B. Baldwin,
H. D. Barnes,
S. H. Barnhart,
B. A. Bertenshaw,
A. M. Blanchard,
E. V. Braden,
W. F. Cummings,
V. H. Doyle,
P. O. Ferris,
D. E. Field,
C. C. Haire,
H. N. Halper,
J. H. Hande,
A. T. Hopkins,
F. C. Kane,
W. R. Kettenring,
E. M. Killough,
P. R. Leete,
Henry Lehn,
W. M. Ludolph,
W. S. MacCulloch,
W. S. McFetridge,
E. W. Metcalf,
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O. M. Miles,
A. T. Powell,
C. P. Richardson,
C. K. Smith,
F. X. Soete,
James Stephenson,
H. J. Stroebel,
D. C. Teal,
A. P. Weymouth,
Louis Wolf,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual. Progress in study—no report.

2. Bibliography on subjects pertaining to records and accounts (Appendix A). Progress report, presented as information.

3. Office and drafting room practices (Appendix B). Progress report, including matter recommended for adoption and publication in the Manual.

   (a) Method of folding and punching drawings.
   (b) Scales of reduction and enlargement.
   (c) Width of rolls of paper and cloth.
   (d) Sizes of drafting equipment and tools.
   (e) Specifications of materials to be used for drawings and drafting.
   (f) Standard system for filing drawings.

4. Maintenance of way reports and records (Appendix C).

   Form for collection of unit cost data for maintenance engineers. Brief progress report.

5. Construction reports and records.

   Forms for recording complete descriptive statement of quantities and other physical characteristics of construction projects. Progress in study—no report.

6. Valuation.

   (a) Resumé of developments of the current year in connection with regulatory bodies and courts.
   (b) Study of Valuation Order No. 3, Reports and Records, to determine if further simplifications are possible.
   (c) Form of Order No. 3 reports in connection with joint projects, federal–railroad.
   (d) Forms for a record of ballast installations (Appendix D). Progress report.

7. Report upon changes in, or revision of I.C.C. Classification of Accounts (Appendix E). Progress report, presented as information.

8. Methods for avoiding duplication of reports and for simplifying and co-ordinating work under the requirements of the I.C.C. and other public authorities (Appendix F). Progress report, presented as information.

The Committee on Records and Accounts,
C. A. Knowles, *Chairman.*

Bulletin 408, January, 1939.

Appendix A

(2) BIBLIOGRAPHY ON SUBJECTS PERTAINING TO RECORDS AND ACCOUNTS

A. P. Weymouth, Chairman, Subcommittee; E. V. Braden, H. N. Halper, C. P. Richardson, C. K. Smith, H. J. Stroebel, D. C. Teal.

The method followed in compiling this bibliography for the current year is similar to that of previous years. Each member of the subcommittee was assigned certain periodicals to review and report important articles pertinent to "Records and Accounts", also any new books or pamphlets of outstanding interest to the Association. The following is submitted as a bibliographical review covering the period from November 1, 1937 to November 1, 1938.

BIBLIOGRAPHY

Books

1. "National Association of Railroad and Utilities Commissioners"—1937 Proceedings of Convention at Salt Lake City. 574 pp., illustrations, maps, tables. Fifty commissions (federal and state) were represented. Discussions by specialists on public utility regulation and accounting practices. Included under the latter are: (a) Continuous Property Records, (b) Retirement Units, (c) Annual Report Forms, (d) Interpretations of Accounting Classifications, and (e) Historical account of first railroad accounting classification—adopted at Saratoga, N. Y., 1879.

2. "The Interstate Commerce Commission Activities, 1887–1937"—269 pp. Prepared by Bureau of Statistics and published March 1937 for use on Fiftieth Anniversary of the creation of the commission April 5, 1887. Historical outline of growth and development of the commission into present organization. Includes useful diagrams of past and present organization and division of work thereunder.

3. "The Interstate Commerce Commission"—A study in Administrative Law and Procedure, Part IV, by I. L. Sharfman, professor of economics, University of Michigan. 550 pp. This concluding volume deals with the commission's organization and procedure more systematically and more fully than was feasible in the earlier volumes. The threads of the entire study are drawn together in a final conclusion, viz, an attempt to analyze and appraise the functions, processes and activities of the Interstate Commerce Commission.

4. "Valuation under Eminent Domain" —By Lewis Orgel. 837 pp. Published by Michie Company. Table of cases. Complete Index. The author specializes in condemnation cases, therefore, writes with intimate knowledge of the practical problems arising in a trial under the law of eminent domain.

5. "Government Regulations of Transportation"—By Emery R. Johnson, professor emeritus of transportation, University of Pennsylvania, published 1938 by Simmons–Boardman Publishing Corp., 649 pp. A discussion of the principles and workings of both federal and state regulations of transportation agencies.

6. "Railways of Thirty Nations"—By P. Harvey Middleton, secretary of the Railway Business Association, published 1937 by Simmons–Boardman Publishing Corp., 328 pp. The subtitle is "Government Versus Private Ownership." The author states that American business is solidly alined against government ownership, as shown by a nation-wide poll. Labor and regulatory rules may force government ownership of railways, he believes, if they are so costly to railway management as to discourage private capital from continuing in this field. The author reviews the history of public ownership of railways abroad.

7. "Railway Accounting Rules"—By the Accounting division of the Association of American Railroads, 2nd Edition, 1937. 233 pp., forms, etc. This book supersedes "Railway Accounting Procedure." Sets forth freight, passenger and disbursement mandatory rules and forms with their respective indices. Arbitration rules with index. Rules of order, Accounting division.

8. "Uniform System of Accounts for Steam Railroads"—By Finance, Accounting, Taxation and Valuation Department of the Association of American Railroads, published 1936. 236 pp. and forms. Contents: Accounting classifications governing investment in road and equipment. Operating revenues and operating expenses, income, profit and loss, and general balance sheet accounts. Train miles, locomotive miles and car miles prescribed by the I.C.C. in accordance with Section 20 of the Act to Regulate Commerce.

PERIODICALS

1. Brief filed February 1938 by the carriers in Ex Parte No. 123—the 15 percent rate increase case. Sets forth that while increases proposed will not immediately restore railroad credit, they are an essential step toward that end and, in fact, are essential to permit many of the carriers to survive at all.

2. "Depreciation and Obsolescence"—Paper by Maurice R. Scharff in April 1938, Proceedings of the American Society of Civil Engineers. The author points out that depreciation is not a simple function of cost, time and rate of interest, but may be the algebraic sum of a wide range of influences the effects of which are difficult to determine. He outlines a method—"a helpful guide in many cases."

Appendix B

(3) OFFICE AND DRAFTING ROOM PRACTICES

D. C. Teal, Chairman, Subcommittee; D. L. Avery, B. A. Bertenshaw, A. M. Blanchard, P. O. Ferris, A. T. Hopkins, W. M. Ludolph, E. W. Metcalf, F. X. Soete, A. P. Weymouth.

The general assignment has been a continuing one, individual problems being taken up each year for study and report. In addition to subjects newly assigned the committee has reviewed the work on welding symbols carried over from last year. The schedule of subjects reported on herein is as follows:

Methods of reproducing drawings.
Reduction and enlargement of drawings.
Methods of folding and punching drawings.
Welding symbols.
Width of rolls of paper and cloth.
Sizes of drafting equipment and tools.
Specifications of material to be used for drawings and drafting.
Standard system for filing drawings.

Reports covering the first three subjects are submitted herewith.

Your committee reports progress on the last five subjects and expects to complete these items next year.

General

In order to establish prevailing methods, the committee submitted a questionnaire to officers of 58 of the Class I railroads, receiving answers from 35. Although it was found impractical to set up results of this questionnaire in tabular form the findings have been carefully abstracted and are introduced into the report as supporting data for the conclusions and recommendations.

In general, standards and practices recommended here are those indicated by plurality of users. Consequently they are not wide deviations from accepted practices.

WELDING SYMBOLS

The welding symbols appearing in the Proceedings for 1938, Vol. 39, pages 673, 674 and 675, which were originally intended for inclusion in the Manual, have been withdrawn by the committee. This action occurred during the 1938 convention and is recorded in the discussion appearing at the end of Vol. 39, page 914. The withdrawal of this material was instituted in order that the committee might consider another code of welding symbols that are being developed by the American Welding Society.

As symbols of the AWS are not quite ready for final approval, the publication and consideration of these for AREA adoption will be postponed until next year.

METHODS OF REPRODUCING DRAWINGS

There is constant demand in railroad work for low-priced, clean-cut, easily-legible reproductions of drawings or specifications that can be used either for record or working purposes, and that can be obtained quickly and as desired in small or large quantities.

Copies of drawings may be required for various purposes, such as:

1. Field working plans for construction work
2. Plans for the manufacture of items in machine shops, foundries or structural steel fabricating plants
3. For preliminary track, sewage or water supply layout work
4. Office records
5. Agreement appendages
6. Legal document exhibits
7. "As Built" records
8. Standard track and roadway items

Questionnaire replies from 35 railroads indicate that three general methods for the reproduction of engineering drawings are in common use. These three methods are light-exposure printing, photostating and photo-lithographic (planograph) printing processes. Beyond a brief definition no attempt will be made to explain the intricate details of each method.

Light-Exposure Printing

Definition

Briefly, this process consists of exposing sensitized paper or cloth to white light through a negative (usually a tracing) of a drawing, and developing the exposed paper in water or chemicals.

The color of the background and of the lines on the print depend on the chemicals used for sensitizing the paper and in the developing operation. The light exposure reproductions may thus be further subdivided as to color scheme or as follows:

1. Blueprints; white lines on blue background, made by exposing "blueprint" paper to light through a tracing and washing the prints in water.

2. White prints; blue lines on white background. To obtain this type, it is first necessary to make a negative from the tracing on brown "Van Dyke" paper. The white prints are then made by exposing regular "blueprint" paper through the brown negative and washing in water.

3. Colored line prints; black, blue, red or brown lines on white background, made by exposing special chemically sensitized paper to light through a tracing or a negative and then washing prints in the proper developing solution.

Analysis

The use of this method requires that the drawing be either made or traced on transparent paper or tracing cloth that will lend itself to the light-printing process. When the original drawing appears on heavy detail drawing paper, the tracing of it will involve extra time and expense, but after the tracing is once made, copies can be quickly and cheaply produced. This method is especially adapted to construction work drawings and other plans subject to frequent changes in design, as tracings can be easily altered and revised copies secured at will.

With the exception of a slight shrinkage of paper during the developing process, the prints are true, clean-cut, easily read reproductions of the tracings from which they were made and are suitable as working drawings or for permanent office records.

Blueprinting is usually the least expensive and most commonly used light-exposure method of reproducing drawings as facilities for making blueprints are ordinarily available. However, the colored line, white background prints are desirable in some cases and when choosing between the two, consideration should be given to the particular use for which prints are intended.

Cost

The unit cost for prints produced by company-owned and operated plants is usually considerably less than prices of the commercial shop. However, the advisability of installing a light-exposure print machine should be governed by the amount of work to be done and access to a commercial establishment.

When enough work is done to give one operator steady employment, company-operated plants can do their blueprinting at an average cost of one cent per square foot for paper copies. The blueprint paper itself costs about half of this amount. Prices for cloth prints will vary directly with cost of the cloth. Colored line prints will run about one and one-half times more than for blueprints due to higher cost of the paper and developing chemicals.

The average prices of commercial blueprint shops in a large eastern city as of September, 1938, were as follows:

Blueprints on paper, from tracings or Van Dyke negatives

Small prints, letter size, minimum	$.05 each
Larger prints, up to 42 in. long	.03 per sq. ft.
Extra large prints, longer than 42 in.	.04 " " "
Specifications and small letter size prints in lots of 100 or more	.03 each

Blueprints on cloth, from tracings or Van Dyke negatives

Small prints, letter size, minimum	.15 each
Larger prints, up to 42 in. long	.07 per sq. ft.
Specifications and small letter size prints in lots of 100 or more	.10 each

Van Dyke negatives

Small, letter size, minimum	.15 each
Larger sizes, up to 42 in. long	.08 per sq. ft.

Colored Line Prints

Approximately one and one-half times greater than for blueprints.

Photostating

Definition

Photostatic reproductions are, in effect, photographs made directly upon the surface of prepared paper by means of a special photostat camera.

Analysis

The principal value of the photostat machine lies in its usefulness in reducing or enlarging drawings to another size and scale (See reduction and enlargement of drawings). It also serves as a convenient and quick method for securing reproductions of drawings, exhibits or specifications that are not set up in the proper form for blueprinting.

Where the production of copies is desired in quantity, the photostatic process is a very expensive method to use. In addition to the relatively high cost, uses of photostatic copies are restricted as the prepared gloss paper on which they are made is easily damaged by folding or rough handling. Scaling of photostats is also unsatisfactory owing to the uneven and unpredictable shrinkage of the paper during the process of development. For these reasons photostatic reproductions are not recommended for design layout or field work. They are best suited for legal document and agreement appendages and for exhibits where scaling accuracy is not important.

When quantity production of copies is desired of drawings or specifications that are not set up for blueprinting, and the time element is not too important, it will be found economical to trace the subject matter for blueprinting or arrange for photolithographic reproductions. In this connection it should be noted that drawings can be photostatically reproduced on prepared transparent material from which reasonably legible light-printed copies can be made and which will stand minor erasures and revisions. This process is, in effect, a quick and convenient method of making tracings. The tracings so produced can be distributed to outlying offices for the making of blueprint copies as and when required. Reduction or enlargement of the original is also possible as it is a photostatic process (See reduction and enlargement of drawings by photostat).

Another short-cut method of making tracings from other tracings is by certain chemical processes which duplicate the original in all respects. These methods are patented, material and directions for development being obtainable from the companies controlling them.

The utilization of photostatic or of chemically reproduced tracings will necessarily depend upon the amount of work to be done, the service for which they and their copies are intended, the time element, and convenience or access to a commercial shop equipped for this type of work.

Cost of Photostating

A photostat can be made for from 12 to 15 cents per sq. ft. The paper itself costs around 4½ cents per sq. ft., while overhead of rent, labor, electricity and chemicals make up the remainder. These prices are based on company-owned and operated photostat machines. Commercial prices will run considerably higher.

The average prices of commercial photostat shops in a large eastern city as of September, 1938, were as follows:

Letter size copies (8½ by 11)	$ .25 ea.
Legal size copies (8½ by 13)	.35 "
Copies up to 18 by 24 in size	.35 to .45 per sq. ft.
Large sizes up to 40 in. width times any length	.50 per sq. ft.
Photostat tracings	1.00 per sq. ft.

Photo-Lithographic (Planograph) Process*

Definition

Lithographic work proper requires that the original subject matter be set up on a special white board or stone from which a zinc printing plate is etched with acid.

* Also known as the offset process.

A less expensive outgrowth of this method is the photo-lithographic or planographic process where the printing plate is made direct from a special photograph of the subject matter. Copies are then printed from the plate.

Analysis

This process has come into extensive use as another method of reproducing drawings, exhibits and other subject matter. For ordinary railroad use copies are made, black lines on white paper. Those obtained from properly made originals are clean cut, permanent and suitable for almost any office or field use. The black on white effect makes them very easy to read.

Photo-lithographic plates are exact replicas of the original insofar as photography will produce, and indistinct designs on the original will appear that way on the prints. It should also be noted that any revision of design or text will necessitate the making of a new plate. For these reasons—drawings or any other material intended for photo-lithographing should be carefully prepared, thoroughly checked and have the approval of all concerned before making the plate.

As the scaling of any photographically reproduced drawing is unsatisfactory—a graphic scale should be set up on the original of drawings that are to be reproduced by the photo-lithographic method.

The economic use of this method depends upon the number of copies required and the expectation that there will be no changes in design or text. Photo-lithographic prints made in small quantities are more expensive than blueprints, due to the cost of the printing plate which has to be absorbed. When made in quantities of 500 or more, they are slightly cheaper than blueprints of the same size.

The chief economy peculiar to this method, however, is effected by photographically reducing drawings to one-half or one-third size before making the printing plate. It should be noted here that a one-half reduction will cut down the area of a drawing to one-fourth of the original size. In the same manner a two-thirds reduction will reduce the printing paper requirements to one-ninth.

Standard drawings are especially adapted for these reduction economics. They are usually drawn to a large scale in order to develop intricate details. The original drawing is then photographically reduced to half size and plated for printing, the original and reduction being designed so that prints can be stored flat in uniform compact standard binders.

Another advantage of the photo-lithographic process is that reproductions can be printed on both sides of paper if desired. This is especially convenient for reproduction of printed matter in pamphlet form.

Cost

As very few, if any, railroads are equipped for making photo-lithographic prints, only commercial prices of the ordinary black on white copies will be considered here. The following table gives the rates furnished to railroads by a commercial lithographing company located in a large eastern city as of September, 1938. These prices are, of course, contingent on the subject matter, being confined to sizes and shapes that can be handled without extra work by the printer.

Number of copies	*Cost per sq. ft. of copy*
100	$.038
200	.021
300	.016
400	.013
500	.011
1,000	.008
2,000	.006

Conclusions

In general and when possible it is recommended that maps, drawings, exhibits and specifications be set up for, and reproduced by the methods indicated below.

Light-Exposure Printing Methods

1. Plans for and records of construction work
2. Plans for manufacture of items in machine shops, foundries or structural steel fabricating plants
3. Maps for preliminary track and sewage or water supply layout work

Photostatic reproduction method

1. Agreement appendages
2. Legal document exhibits

Photo-lithographic reproduction method

1. Standard plans

The report on "methods of reproducing drawings" is offered as information.

REDUCTION AND ENLARGEMENT OF DRAWINGS

The reduction or enlargement of a drawing may be required for any one of several reasons. Smaller sized reproductions are often needed:

1. For convenience in handling
2. To eliminate bulky folded attachments
3. To secure small-sized and small-scale layout plans for general preliminary studies
4. To secure drawings that can be bound without folding into standard size binders and reports such as:
   (a) Standard drawings
   (b) Agreement appendages
   (c) Legal document exhibits

Drawings may require enlargement for any one of the following reasons:

1. To facilitate comprehension of intricate details
2. To obtain large scale plans for detail layout work
3. For advertising, lecture or courtroom exhibits
4. To bring drawing to a larger and more convenient scale

There are several methods of changing the size of drawings, each adapted to the purpose for which the reproduction is desired. Reduction or enlarging may be accomplished by:

1. Replatting with scale or proportional dividers
2. Replatting with pantograph
3. The photostatic process

Definitions

Proportional Dividers—An instrument for scaling and replatting drawings to a reduced or enlarged scale. It consists of two legs six to nine inches long with fine steel points at their extremities. The legs are connected by and turn on a movable pivot, the position of which may be so adjusted that the ratio of the distance between one pair of points to the distance between the other pair of points may be set as desired.

Pantograph—An instrument for copying drawings or designs on an enlarged or reduced scale, by tracing over the original with a tracer pointer, copy being produced at another location on drawing board by a pencil pointer.

Photostatic Process—See under "Methods of Reproducing Drawings."

Analysis—Replatting Methods

The replatting methods are used mostly for reducing or enlarging right-of-way and track maps. Replatting is always advisable where a large-scale location map is needed for detail layout work, as this method tends to be more accurate than others. The accuracy, however, is obtained at the expense of time and drafting labor. Replatting by hand requires longer time than by other methods, and when completed the reproduction has to be traced, photostated or photo-lithoplated for further copies.

The pantograph machine provides a faster and easier method for copying drawings to a reduced or enlarged size than the hand platting process. However, this apparatus requires rather delicate adjustment and very careful handling in order to produce good results. Many offices do not consider it essential drafting room equipment and arrange to do their reduction or enlarging by other means. Pantograph reproductions necessarily appear in pencil and have to be handled in the usual manner for further copies.

For both hand methods, speed and accuracy will depend on the skill and industry of the draftsman. The cost cannot be estimated in units as there are too many variable factors to consider.

Analysis—Photostatic Method

The photostatic process is the most commonly used method of reducing or enlarging drawings as it is the quickest and usually the least expensive. Reduction or enlargement is accomplished at the same time that the photostat is made, ratio of change being governed by distance between the object and the camera.

In this connection it should be noted that the average photostat machine can only reduce to half size or enlarge to double size with one operation. Any change beyond these limits will necessitate two or more operations.

Scaling of drawings reduced or enlarged by the photostatic method is particularly unsatisfactory owing to difficulty in maintaining accurate change-of-size ratio during the process.

When more than 15 or 20 copies are desired, photostatically reduced or enlarged prints may be traced for blueprinting or plated for litho-printing. Here again, accurate scaling of copies is unsatisfactory. As a protection against errors and to enable more accurate scaling, a graphic scale should be set up on the original of all drawings that are to be reduced or enlarged by the photostatic process.

In comparing the various methods, attention must be given to the cost of making the first reduction or enlargement as well as the cost of making copies. Disregarding other considerations the photostatic process is the quickest and most economical method of making an original reduction or enlargement. After the original has been made, however, it should be traced or plated for economic production of prints. (See methods and costs of reproducing drawings).

Analysis—Scales of Reduction and Enlargement

Reduction is usually made from one-half to one-fourth the original size, depending on requirements, although it can be carried further if necessary. Where legible prints are desired it is not advisable to reduce more than two-thirds. In this connection, drawings that are made with reduction in mind should have weights of lines and size of lettering increased in proportion to the reduction desired. (See Manual, pages 11–76.3 to 11–76.6 covering recommended practices for lettering and line work).

Enlargements are usually made from two to four times the original size, depending on the purpose of the enlargement.

For both reductions and enlargements, exactness as to outline and scale will depend upon the method used and the carefulness and skill of the draftsman or photostat machine operator.

Practically all of the 35 railroads replying to the questionnaire stated that they used both the hand replatting and photostatic processes for their reduction and enlargement work and that the choice of method was governed largely by the particular purpose for which the work was intended. Twenty-two railroads preferred and used the photostatic method whenever possible. Seven replies mentioned the pantograph as their principal aid, and six favored use of the hand replatting by scale and proportional dividers.

Conclusions

In general when reduced or enlarged plans are to be used for design or layout work requiring accurate scale measuring, the hand replatting methods should be used.

When reduction or enlargements are desired for record or exhibit purposes, the faster and more economical photostatic method should be used.

Owing to the great variety of usage requirements it is believed impractical to make any recommendations regarding scales of reduction or enlargement. In lieu of recommendations it is suggested that they be reduced or enlarged as required and by the most desirable method available.

The report on "reduction and enlargement of drawings" is offered as information.

METHODS OF FOLDING AND PUNCHING DRAWINGS

It is frequently necessary in office and drafting room work to fold and otherwise prepare drawings for attachment to correspondence files, for binding into special cover back reports or for storage in the record files. The adoption of standard methods of preparing drawings for these purposes is essential to efficient office routine.

Folding Drawings

Two general methods of folding blueprints are favored above all others. These two methods are almost identical as far as folding procedure is concerned, the difference being in the position of the binding margin or ear. One method requires that drawings be laid out and trimmed for folding with the binding margin projecting from the top. The other method calls for a binding margin at the left-hand edge.

Folding for Top Binding

In preparing for top attachment it is first necessary to lay out the margin so as to provide a suitable projecting ear at the top left-hand corner of the drawing. After trimming to this design the prints are folded in an accordion-like manner from the left

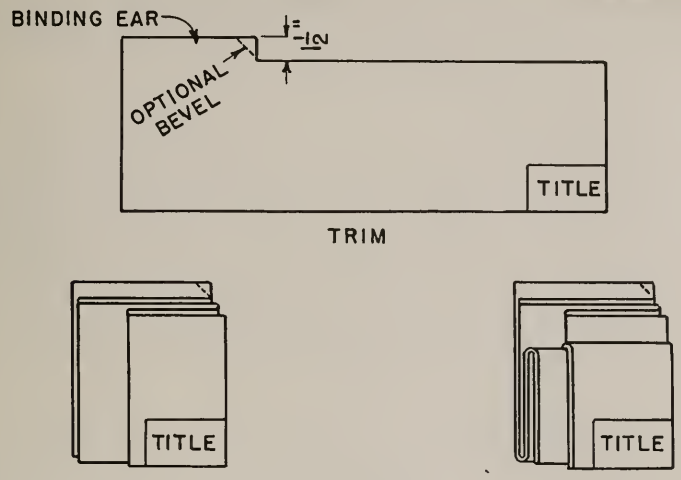

FIG. 1
RECOMMENDED METHOD OF
FOLDING DRAWINGS FOR TOP BINDING

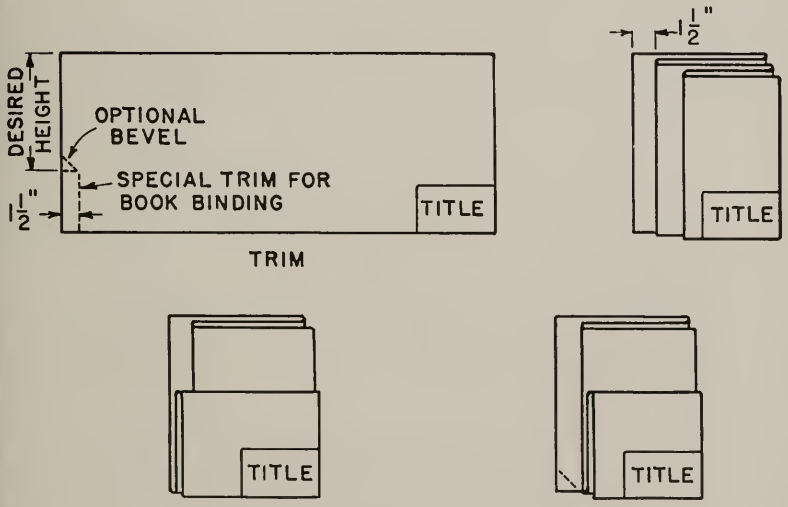

FIG. 2
RECOMMENDED METHOD OF
FOLDING DRAWINGS FOR LEFT SIDE BINDING

side, with the last two folds adjusted so that title block will appear in the lower right hand corner of the folded print. Large-size drawings are brought to the desired height by folding from top to bottom in the same manner. Fig. 1 graphically illustrates the top binding method of folding described above.

Folding for Left-Side Binding

In this method the drawings are folded from the left side in the same general manner as described for top binding. The location of binding margin, however, necessitates that the second fold be made 1 to 1½ in. narrower than the first in order to leave this margin free. The preparation and folding of drawings for left side binding is illustrated in Fig. 2.

Another, but not very popular method of preparing larger size drawings for letter attachment or for binding, is to make the horizontal folds before the vertical ones. The location of binding ear can be varied to suit requirements.

Analysis of Folding Methods

There are times when usage will determine the location of the binding ear. For instance, legal documents such as agreements are bound at the top, and drawings for attachment must necessarily be adapted to this requirement. For the same reasons, blueprints, to be included in cover-backed reports, will have to be prepared for left-side binding.

A left-side margin arrangement is usually preferable for attachment of blueprints to correspondence files, as less time is required for the trimming of prints.

The methods illustrated in Fig. 1 and 2 are well suited for railroad office and drafting room use as they are adaptable to almost any purpose. The vertical accordion folds permit drawing to be pulled out from the file or binder without detaching from it and to be opened up for examination like a book to the desired place. The necessity of unfolding and spreading out the entire blueprint in order to inspect any one part makes the third (horizontal fold first) method objectionable and unsuited.

Some railroads make a practice of folding large drawings to a size slightly smaller than that of the letter head files to which they are to be attached, in order to allow for uneveness of folding. All drawings intended for binding into cover-backed reports, however, should be folded to the exact size of the other sheets.

Of the 35 answers received, 12 railroads used the top binding accordion folding method illustrated in Fig. 1, while 14 used variations of the left-hand edge binding shown in Fig. 2. Only four railroads used the horizontal fold first system. Five replies were too brief to be classified.

Conclusions

As occasions will arise in office and drafting room work when both top and left-side binding will be required, methods should be adopted suitable to either purpose.

The methods illustrated in Fig. 1 and 2, already used by the majority of railroads, and being well suited to office and drafting room requirements, are recommended by your committee as standard practice.

The top binding method illustrated in Fig. 1 is recommended for legal document appendages and letter files.

The left-side margin method shown in Fig. 2 is recommended for attachment of drawings to letter files and for binding work.

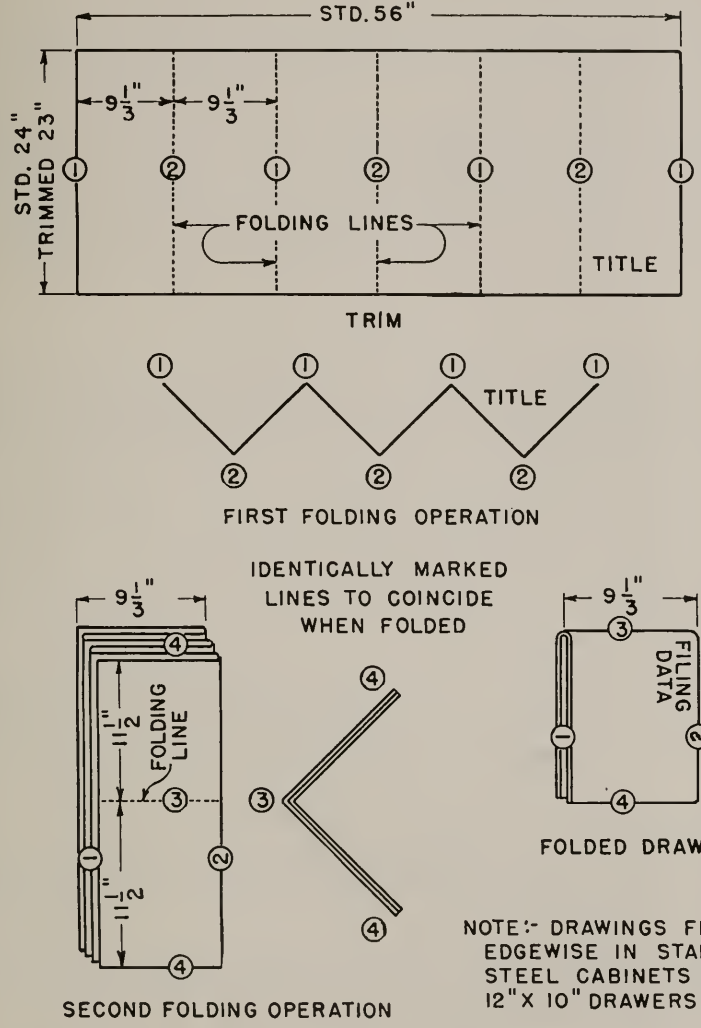

FIG. 3
RECOMMENDED METHOD OF
FOLDING RIGHT OF WAY MAPS FOR
STORAGE IN OFFICE FILING CABINETS

Folding Drawings for Storage

The questionnaire developed three general methods of preparing blueprints for storage in plan filing cabinets.

One method is to roll and store blueprints in pigeon hole cabinets.

A second method is to lay them flat in shallow, horizontal type drawers, folding the larger prints to fit the drawers.

The third method is to fold prints to letter-head size and store edgewise in standard 12-in. by 10-in. drawer filing cabinets.

The folding method illustrated in Fig. 3 is used by several railroads for storing ICC right-of-way or valuation blueprints. The accordion system is used and folding is started so that the white back side of the print appears on the outside of the folded drawing and can be used for marking mile-post location and other identification notes.

Analysis

Standard steel filing cabinets with 12-in. by 10-in. pull-out drawers are very convenient for edgewise storage of folded prints. A complete set of valuation maps for the average railroad, folded as illustrated in Fig. 3 can be stored in four or five drawers. This method permits easy handling of prints in and out of the filing cabinet as well as for office and field uses, and is adaptable for the filing of any large blueprints that can be folded for storage without impairing usefulness.

Eight of the 35 railroads use the rolled pigeon-hole filing, 10 the shallow flat-drawer storage and 7 prefer the method of folding to approximate letter-head size and storing edgewise in suitable cabinets. Eight railroads use all or combinations of these methods. Two replies stated that their companies did not keep blueprints for permanent records.

Conclusions

It would be difficult to recommend any one of the above methods over the others, as the best for the individual must be the one suited to the filing cabinet facilities available. Disregarding other factors, the method shown in Fig. 3 has the advantage of compactness and requires smaller filing cabinet space than either of the other two.

Punching of Drawings

The questionnaire answers indicate that about the only punching of drawings or blueprints is done in connection with their attachment to files or for their insertion in removable cover, post binder books where size and location of punchings depend on size and spacing of the binder posts.

For obvious reasons it is believed impractical to attempt standardization of methods of punching drawings or blueprints. In lieu of recommendations it is suggested that they be punched as and where needed.

The report on "methods of folding and punching drawings" is presented as information.

Appendix C

(4) MAINTENANCE OF WAY REPORTS AND RECORDS

H. L. Restall, Chairman, Subcommittee; Anton Anderson, D. L. Avery, E. V. Braden, W. F. Cummings, P. O. Ferris, W. M. Ludolph, W. S. McFetridge, O. M. Miles, A. T. Powell, C. K. Smith, F. X. Soete, D. C. Teal, A. P. Weymouth.

This year the committee has had under consideration a form for the analysis of Maintenance of Way and Structure Accounts, Exhibit 1, which allows comparison by accounts of the cost of maintaining the property expressed in terms of a dollar base and a mileage base. This comparison to be made between divisions or systems.

This report is offered as a progress report.

Appendix D

(6) VALUATION

S. H. Barnhart, Chairman, Subcommittee; C. A. Knowles, H. L. Restall, F. B. Baldwin, H. D. Barnes, B. A. Bertenshaw, V. H. Doyle, P. O. Ferris, D. E. Field, C. C. Haire, A. T. Hopkins, F. C. Kane, W. R. Kettenring, E. M. Killough, P. R. Leete, Henry Lehn, W. S. MacCulloch, W. S. McFetridge, E. W. Metcalf, O. M. Miles, C. P. Richardson, James Stephenson, H. J. Stroebel, Louis Wolf.

(a) Resumé of Developments of the Current Year in Connection With Regulatory Bodies and the Courts

The Interstate Commerce Commission appropriation for the fiscal year beginning July 1, 1938, includes $640,000 for its Bureau of Valuation, a reduction of $60,000 from the previous year. As of November 1, 1938, the bureau had a total personnel of 188, of which 11 are in the Administrative section, 53 in the Engineering section, 52 in the Land section, and 72 in the Accounting section.

During the year 1937 Class I carriers charged to Account 459, Valuation Expenses, an amount of $796,944, contrasted with $1,037,387 for the year 1936.

Progress has been made by carriers in the filing with the Bureau of Valuation of annual returns on B. V. Form 588, which contain the details of property changes necessary to bring previous engineering inventories forward to new valuation dates. As of November 1, 1938, all Class I carriers had filed these returns through the year 1934, 97 percent through the year 1935, 61 percent through the year 1936, and 29 percent through 1937.

The Engineering section of the Bureau of Valuation has completed revised inventories of all Class I carriers through the year 1927, 64 percent of the mileage through 1930, 53 percent through 1932, 31 percent through 1933, 18 percent through 1934, and 6 percent through 1935. The work of the Accounting section in preparing summaries of original cost, and that of the Land section in revising land values, has advanced to about the same extent.

A noteworthy occurrence in railroad valuation during the year was the preparation by the Bureau of Valuation of estimates of reproduction cost new and less depreciation, original cost, original cost less depreciation, land values, and working capital, for individual carriers as of December 31, 1936, together with findings by the commission of approximate aggregate values by classes of railroads, by regions and districts. The underlying figures were introduced and received in evidence in Ex Parte 123—Fifteen Per Cent Rate Case, decided March 8, 1938. The commission's decision translated the

EXHIBIT 1

THE NORTH AND SOUTH RAILROAD

ANALYSIS OF MAINTENANCE OF WAY
and STRUCTURE ACCOUNTS

Division/System: _____ Year _____
Miles of Road: _____
Miles of Main Tracks: _____
Miles of All Tracks: _____

M/S Acct. No.	ACCOUNTS NAME	R&E Acct. No.	Original Cost or/ I.C.C.Cost of Reprod. New 1910-14 prices plus Net A&B Dec. 31 19____	TOTAL M. of W. & Structures Including Constr. Oper.	TOTAL M. of W. & Structures Excluding Constr. Oper.	Cost of Maintenance of Way & Structures Per Dollar Investment Including Constr. Oper.	Per Dollar Investment Excluding Constr. Oper.	Per Mile of Road	Per Mile of Main Track	Per Mile of All Tracks	Per Mile of Equated Track Mile	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
202 to 269		3 to 37										

Column 4 - I.C.C. Cost of Reproduction New plus net A. & B. to be used in lieu of Original Cost.

Column 5 - Including A. F. E. Operating Expenses.

Column 6 - Excluding A. F. E. Operating Expenses.

underlying figures into approximate values as described, which aggregated $21,060,000,000 for all carriers contrasted with $26,384,993,000 of book investment. The exhibits (Nos. 68 and 69) contain a description of the general methods employed in the preparation of the underlying estimates. This is the first occasion that aggregate values were found by the commission since Ex Parte 74, decided in 1920. In that proceeding the aggregate value found for all railroads was $18,900,000,000, compared with a book investment of $20,040,573,000.

In addition to the findings in Ex Parte 123, during the year, at the request of the commission, the bureau prepared reports of the "elements of value" or underlying valuation figures upon additional roads under reorganization and introduced them in the record. In all, 18 cases have been completed, covering 58,769 miles. In the later cases the reports show the property segregated by mortgage divisions.

The various joint committees continued their co-operative cost data studies upon the more important items entering into railroad construction so as to keep informed as to current trends, and their reports and conclusions were circulated among the carriers. The 1937 edition of "Railroad Construction Indices" was prepared and released by the Bureau of Valuation. Copies of these reports may be obtained from Mr. E. H. Bunnell, vice-president, Association of American Railroads.

Cancellation of Certain Valuation Orders of the Interstate Commerce Commission

Under the date of November 10, 1938 the Interstate Commerce Commission issued an order cancelling certain orders, theretofore entered, which for various reasons had become obsolete, as follows:

Valuation Orders Nos. 2 and 10 relating to abandoned property; Valuation Order No. 9 relating to transportation of employees, supplies and cars of the Bureau of Valuation; Valuation Order No. 13, relating to schedules of property owned or used by steam carriers; and Valuation Order No. 21, relating to specifications for maps, charts, and schedules of telegraph and telephone properties in so far as applicable to railroads.

Court Decisions

During the year a number of cases involving valuation were decided by federal and state courts, and brief mention is made of the more important ones. In the United States Supreme Court the rehearing in the Pacific Gas and Electric Case reported in last year's bulletin was decided on January 3, 1938. This case attracted considerable interest and a number of regulatory commissions intervened in the belief that the court might pass upon the question of whether entire weight can be given historical cost and none to reproduction cost in fixing the rate base value. The court did not pass upon this point. The Supreme Court, in disposing of the issue of due process, found that a proper hearing had been had in accord with the state law; that it was conducted fairly; and stated that they did not sit as an appellate board of revision, but to enforce constitutional rights. If the rate-making agency of the state afforded a fair hearing and did not determine its conclusions arbitrarily, the only question left for judicial determination was whether the rates fixed were confiscatory, and as the lower court had not passed on this issue the case was remanded to the District Court. Subsequently, on September 8, 1938, the District Court found that "the charge of confiscation is not clearly shown by this record." In a lengthy opinion the District Court stated that the decisions of the Supreme Court are uniform to the effect that both original cost and cost of reproduction new less depreciation should be considered in arriving at the fair value of the property as this would be more nearly fair to the utility and to

the public than a rate base fluctuating with every turn of the market value of supplies and the cost of labor, and that the rate base should lie somewhere between the historical cost depreciated and the reproduction cost new depreciated. The opinion also contains an interesting discussion of depreciation and the use of straight line or sinking fund methods arising out of the complications of the case before it.

Another Supreme Court case decided on January 3, 1938, was that of the Indianapolis Water Company, a rate proceeding. The Supreme Court remanded the cause to the District Court for further determination of whether a valuation made in 1933 made applicable to a decress entered in 1935, without taking account of changed conditions in the interval, would be open to an issue of confiscation. Subsequently a stipulation was entered by the parties to the case in the District Court agreeing that the matter lie without further proceedings except upon 30 days' notice of either party, which was accepted by the District Court, with the reservation that the court would dispose of the cause if there should be unreasonable delay.

On May 31, 1938, the Supreme Court held in the Denver Union Stock Yards Case that it is not necessary to appraise going concern value as a separate item in the valuation of a public utility for rate-making purposes and upheld the rates prescribed to yield a return of 6½ percent. The court said that going concern value was considered; that in adopting the value of land and cost of reproduction new less depreciation of structures, consideration was given to the element of going concern value; that adequate allowance had been included and that appellant's plant without business, present or prospective, would be worth much less than the cost figures found.

The Supreme Court granted the Southwestern Bell Telephone Company a review of an Oklahoma State Supreme Court decision upholding an order prescribing a reduction in rates. One of the reasons the telephone company contended the order was invalid was the method of valuation employed by the commission. The valuation was obtained by subtracting the depreciation reserve from original cost and other facts considered irrelevant.

In the Utah Supreme Court in the case of Utah v. S. P. Co., et al, the court held the provisions of the state constitution were violated by a statutory requirement that the valuation of utilities fixed by the Public Service Commission should be accepted by the Tax Commission for tax purposes. The court found that fair value as a rate base and the value in money for tax purposes are not necessarily the same.

(b) Study of Valuation Order 3 Reports and Records to Determine if Further Simplifications Are Possible

Substantial progress has been made in the study and investigation of this subject but no specific report can be made this year.

(c) Form of Order 3 Reports in Connection With Joint Projects, Federal–Railroad

Your committee has given much thought and time to the consideration of the form of Valuation Order 3 reports for joint governmental–railroad projects, particularly those covering the several kinds of highway crossings, but due to difficulties arising as to the proper inventory classification of such property, the outline or form of reports cannot as yet be developed.

(d) Forms For a Record of Ballast Installations

After exhaustive investigation of this subject the committee finds:

(1) That the development of a usable record for ballast installations is primarily dependent upon the needs or requirements of the engineering, maintenance and accounting organizations of an individual carrier.

(2) That, knowing such individual carrier requirements, the development of a form for such a record is a simple, rather than a complicated, procedure.

(3) That due to lack of uniformity in the requirements of individual carriers no general forms have as yet been developed, but the committee is continuing its study of the subject.

The report is submitted as information with the recommendation that the subject be continued.

Appendix E

(7) CHANGES OR REVISIONS IN I.C.C. CLASSIFICATION OF ACCOUNTS

H. D. Barnes, Chairman, Subcommittee; Anton Anderson, A. M. Blanchard, W. F. Cummings, D. E. Field, C. C. Haire, H. N. Halper, J. H. Hande, W. R. Kettenring, Henry Lehn, W. M. Ludolph, O. M. Miles, A. T. Powell.

There have been no changes in the accounting classifications subsequent to this committee's last report (pages 711–714, Volume 39, Proceedings for 1938). The Bureau of Accounts of the Interstate Commerce Commission have, however, released three series of accounting rulings. Only those involving the investment in road and equipment and other accounts used incidental to accounting for construction, maintenance and retirements are referred to in this report. In most cases the rulings have been paraphrased and full text of a ruling should be consulted before applying its provisions.

Accounting Case Series No. 15 (June 7, 1937)

Case A-120. Pertains to the use of Account 603, Credits From Retired Road and Equipment, in connection with the sale of equipment.

Case A-122. Distinguishes between storage warehouses the costs of which are includible in Account 22, Storage Warehouses, and those, the costs of which are includible in Account 705, Miscellaneous Physical Property, as, "The storage warehouses, the cost of which is includible in Account 705, are those which are not operated in connection with transportation service of the accounting company. Where a warehouse is used for commercial storage and is also operated by the carrier for the receipt or delivery of freight which is transported by the accounting carrier, its cost is includible in Account 22."

Case A-125. Provides that amounts expended prior to the date new equipment is placed in service will not be included in the depreciation base until the equipment is placed in service and requires an explanation of such differences in the annual report to the commission.

Case A-126. Prescribes the accounting for maintenance, rental, etc., in connection with pole line jointly owned by a carrier and telegraph company.

Accounting Case Series No. 16 (December 10, 1937)

CASE A-134. Provides that:

(a) The cost of second-hand rail used to replace rail of the same pattern weight, new when laid, shall be charged to operating expenses.

(b) The cost of second-hand rail used to replace rail of a heavier pattern weight, new when laid, shall be charged to operating expenses and the decrease in weight credited to Account 9, Rails, and charged to Account 214, Rails, at the current price of new rail.

Accounting Case Series No. 17 (May 31, 1938)

CASE A-136. Provides that, in case an industry ceases to use a track constructed (beyond the clearance point) at its expense, the industry retaining ownership in the material, and the carrier continues to use the track as a permanent track, the fair value of the track, consideration being given to its present condition, shall be charged to Account 701, Investment in Road and Equipment. This amount, less the amount paid the industry for salvage, shall be credited to Account 606, Donations.

CASE A-137. Provides that the entire cost of grade crossing flasher light protection installed at the joint expense of a carrier and a state or other public authority shall be charged to the carrier's investment account when the signals are the property of the carrier and maintained and operated by it. The portion of the cost contributed by the public authority shall be credited to Account 754, Grants in Aid of Construction.

CASE A-140. States that amounts included in Account 39, Public Improvements—Construction, are not written off (retired) except when a section of road is retired, for the reason that such amounts are not investments in transportation property.

CASE A-142. Prescribes that the investment in devices used to melt snow and ice at switches shall be accounted for as follows: "Hand portable thawing torches, in Account 38, 'Roadway small tools.' Hydrocarbon, electric, or other heaters set up under the switches, in Account 10, 'Other track material.' The investment in storage tanks for, and pipes conveying the fuel to the heating devices at interlocking plants should be included in Account 27, 'Signals and Interlockers.' Heating systems to which power is supplied by electricity, steam or hot water power lines when operated as part of signal and interlocker systems should be included in Account 27, 'Signals and Interlockers'; otherwise, in Account 31, 'Power-Transmission Systems.' "

CASE A-143. Provides that the replacement of, "Any portion of a right-of-way fence should be accounted for in accordance with Section 7, general instructions in the Classification of Investment in Road and Equipment, 'Property Retired and Replaced,' subject to provisions of the minimum rule, paragraphs (a), (b), (c) and (d) of Section 2, general instructions, in the Classification of Investment in Road and Equipment."

The report is submitted as information with the recommendation that the subject be continued.

Appendix F

(8) METHODS FOR AVOIDING DUPLICATION OF REPORTS AND FOR SIMPLIFYING AND CO-ORDINATING WORK UNDER THE REQUIREMENTS OF THE I.C.C. AND OTHER PUBLIC AUTHORITIES

F. B. Baldwin, Chairman, Subcommittee; H. D. Barnes, S. H. Barnhart, V. H. Doyle, C. C. Haire, H. N. Halper, F. C. Kane, C. A. Knowles, P. R. Leete, W. S. MacCulloch, C. K. Smith, Jas. Stephenson, Louis Wolf.

While no definite matters were referred to your committee for consideration during the year, the following developments, presented as information, indicate the progress that is being made in securing relief in reporting requirements of various governmental bodies.

Your committee's report of last year presented as information a list of reports filed by railroads with various state and federal authorities, which was circulated among accounting officers with circular of E. H. Bunnell, vice-president, AAR, dated August 25, 1937, with the request that carriers review the reports furnished and submit recommendations which could be made to the department affected. Following receipt of these replies, J. J. Pelley, president, AAR, under date of May 3, 1938, addressed a joint letter to W. M. W. Splawn, then chairman of the Interstate Commerce Commission, and President A. M. Mahood, of the National Association of Railway and Utilities Commissioners, enclosing a copy of this compilation and stating that a study of it led to the conclusion that a number of the reports were not essential for regulatory purposes and requesting that the reports be reviewed by the commissions for the purpose of curtailing or eliminating many of them and further, that reports required be limited to essential data, in view of the depressed and critical state of the railway industry. Following this review, representatives of the carriers would confer with the commission's representatives.*

Under date of May 9, 1938, Chairman Splawn replied that he would be pleased to have the commission's representatives confer regarding any eliminations that could reasonably be made in routine statistical reports filed by the railroads. A request was also made that a specific list be furnished of the reports considered as non-essential for regulatory purposes which would be discontinued by the railway companies if not required by the Interstate Commerce Commission.

Mr. Mahood's reply of May 16 referred the matter to L. R. Bitney, chairman of the association's Committee on Statistics and Accounts of Railway Companies. No further request has been made upon the state commissions pending the consideration of the several recommendations to the Interstate Commerce Commission.

In response to Chairman Splawn's request, further consideration was given by valuation and accounting officers to records kept and reports made as a consequence of the commission's orders and regulations, and under date of August 10, 1938, Mr. Pelley again wrote Chairman Splawn, submitting the carrier's recommendations.

Two conferences have resulted from the recommendations submitted by Mr. Pelley:

The first conference was held on October 14 by a committee of accounting officers with the Bureau of Statistics. The carriers were informed that their proposals had

* Copies of the letter of Mr. Pelley of May 3, 1938, of the letter of Chairman Splawn of May 9, 1938 and of the letter of Mr. Pelley of August 10, 1938, may be secured from E. H. Bunnell, vice-president, AAR, Washington, D.C:

received consideration of the Bureau of Statistics, but because the principal recommendations conflicted with the matter of cost finding, now embraced in Docket 122, it would not be possible to give an answer until the issues were presented and decided in that case. As yet no date has been set for this proceeding. One or two suggestions relating to the furnishing of quarterly reports instead of monthly reports were left open for further discussion with the bureau.

The second conference related to valuation, and a meeting with Director Lewis, of the Bureau of Valuation, took place on October 25. At this conference a committee of valuation engineers together with an accounting representative (composed of Messrs. Roach, Baldwin, Barnhart, Lyle and Knowles, and Mr. Hess), presented a preliminary report, containing the suggestions of the committee which recommended a shortened procedure in recording and reporting under Valuation Order No. 3. The carrier's program embraced three points: (1) The possible revision of Order 3 and Supplements 4 and 5 thereto; (2) additional shortcuts which would be permitted under existing orders; and (3) a wide circulation among the carriers of all approved practices now in use. Arrangements were made for the committee of valuation engineers to confer further with representatives of the Bureau of Valuation, in order to discuss the proposals in detail and work out a procedure acceptable to the bureau.

Another matter collateral with the endeavors of the carriers was a request made by President Roosevelt in a letter to the Central Statistical Board of May 18, 1938, calling for a survey to determine the nature, duplications and diversity of reports now required by federal agencies of business and industry and requesting the board to report to him by January 1, 1939 with its recommendations, looking toward consolidations and changes consistent with efficiency and economy both to the government and to private industry.

A committee of accounting officers conferred with that board on October 27, and presented a recommendation to the effect that steps should be taken to work out a program whereby one report covering payments of salaries and wages, which would answer the purpose of the Bureau of Internal Revenue, the Railroad Retirement Board, and the Unemployment Compensation Commissions and all state agencies receiving the same information. It was also explained to the Central Statistical Board that the carriers were now engaged in co-operative work with the Interstate Commerce Commission, looking to a simplification and reduction of reports now made and that there were no separate recommendations to make to the Central Statistical Board. A copy of proposals submitted to the Interstate Commerce Commission was left with the board, for its information.

The report is submitted as information with the recommendation that the subject be continued.

REPORT OF COMMITTEE 17—WOOD PRESERVATION

C. F. Ford, *Chairman;*
Wm. G. Atwood,
Dr. S. J. Buckman,
Walter Buehler,
C. S. Burt,
G. B. Campbell,
Dr. Wm. F. Clapp,
H. R. Condon,
E. A. Craft,
H. R. Duncan,
E. B. Fulks,
W. R. Goodwin,
L. H. Harper,
L. B. Holt,
G. R. Hopkins,
H. E. Horrocks,
R. S. Hubley,
R. P. Hughes,
M. F. Jaeger,
Dr. A. L. Kammerer,
Edward Kelly,
W. S. King,
A. M. Knowles,
A. J. Loom,
R. S. Belcher,
Vice-Chairman;
F. D. Mattos,
L. J. Reiser,
F. B. Robins,
Dr. Henry Schmitz,
L. B. Shipley,
O. C. Steinmayer,
G. C. Stephenson,
T. H. Strate,
W. A. Summerhays,
Dr. Hermann von Schrenk,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A). Progress report.
2. Service test records for treated ties (Appendix B). Progress report.
3. Piling used for marine construction (Appendix C). Progress report.
4. Effect of preservative treatment by use of
   (a) creosote and petroleum.
   (b) zinc chloride and petroleum. (Appendix D). Progress report.
5. Destruction by termites and possible ways of prevention (Appendix E). Progress report.
6. Effect on preservative in treated ties in track due to blowing off locomotives on line of road, collaborating with Committee 13—Water Service, Fire Protection and Sanitation (Appendix F). Progress report.
7. Incising of all forest products material. Progress in study—no report.
8. Investigations being made for the determination of toxicity value of creosote and creosote mixtures. Progress in study—no report.
9. Present practice as to preservatives used (Appendix G). Progress report.

The Committee on Wood Preservation,
C. F. Ford, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

O. C. Steinmayer, Chairman, Subcommittee; R. S. Belcher, S. J. Buckman, W. Buehler, E. B. Fulks, H. E. Horrocks, F. D. Mattos, Prof. H. Schmitz, L. B. Shipley, G. C. Stephenson, Dr. H. von Schrenk.

The committee reports progress in its study of the specifications for treating processes and specifications for the treatment of wood in the various forms and species ordinarily encountered Matters, however, have not been perfected to the point which will permit of submitting a revision of present standards at this time.

Bulletin 409, February, 1939.

SPECIFICATION FOR CREOSOTE ANALYSIS

I WATER

An editorial revision of the present method as given on Pages 17–23 and 17–24 in the Manual appears desirable. Further, an alternative method has been devised which may be found preferable under certain conditions. This alternative method has been adopted by the American Society for Testing Materials and the American Wood-Preservers' Association. Also, the revision of the present standard, if adopted, will result in the specifications conforming again to those of these two associations.

The committee recommends:

(a) The acceptance of the editorial changes which have been made in the present standard for water determination designated as Method No. 1 which follows.

(b) The adoption of an alternative method for water determination designated as Method No. 2.

SPECIFICATIONS FOR CREOSOTE ANALYSIS

1939

I WATER

METHOD NO. 1

101. Scope

This is an accurate method for determining the percentage of water in creosote; also for dehydrating creosote containing water in preparation for the distillation test as described in IV Distillation. Its use is indicated for creosote containing water in excess of 3 percent. The method is suitable for creosote, tar, petroleum and mixtures thereof. The alternative method (No. 2) is more convenient and rapid where the determination of water only is desired. For creosote containing water below 3 percent follow regular distillation procedure, IV par. 410 f.

A. Apparatus

102. Still

A vertical, cylindrical copper still with removable flanged top and yoke of the form and approximate dimensions shown in Figs. 1704 and 1705 shall be used.

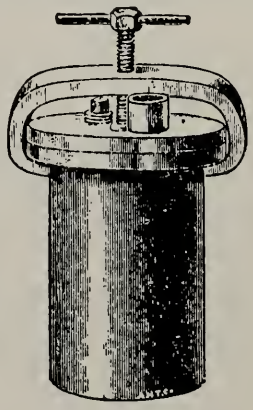

FIG. 1704.—Copper Still.

103. Thermometer

The thermometer shall conform to specification given in IV Distillation.

104. Condenser

A copper trough condenser shall be used, with straight-walled glass tube, having approximately the form and dimensions shown in Fig. 1705.

105. Separatory Funnel

A separatory funnel of the form shown in Fig. 1705 shall be used having a total capacity of 120 ml. and the outlet graduated in fifths of a milliliter.

B. Sampling

106. Sample

The sample must be representative of the material to be tested and the portion of the sample used for the tests must be representative of the sample itself. Deviation from this requirement shall not be permitted.

Note—The difficulties in obtaining proper representative samples for this determination are usually great, so that the importance of proper sampling cannot be too strongly emphasized.

C. Procedure

107. Assembling Apparatus

The apparatus shall be assembled as shown in Fig. 1705.

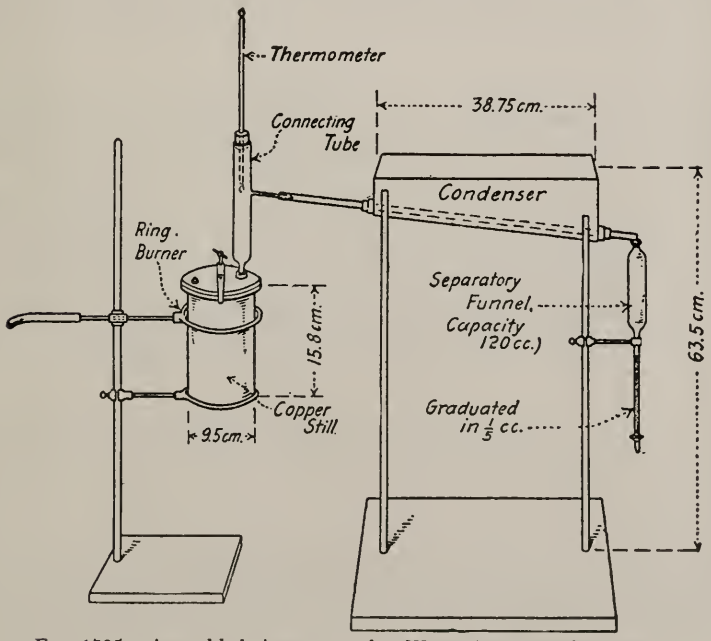

Fig. 1705.—Assembled Apparatus for Water Test, Method No. 1.

108. Test

Measure 200 ml. of the sample in a graduated cylinder and pour into the copper still, allowing the cylinder to drain into the still for several minutes. Attach lid and clamp, using a paper gasket slightly wet with oil around the flange of the still. Apply heat by means of the ring burner which should be placed just above the level of the oil in the still at the beginning of the test and gradually lowered after most of the water has distilled over. Continue the distillation until the vapor temperature, indicated by the thermometer with the bulb opposite the offtake of the connecting tube, reaches 205 degrees C. Collect the distillate in the separatory funnel. When the distillation is completed and a clear separation of water and oil in the funnel has taken place, read the water by volume and draw off. All light oils that have distilled over with the water shall be returned to the oil in the still. The dehydrated creosote in the still is then ready for the distillation test described in IV Distillation.

Method No. 2

109. Scope

This method of test determines water in a sample by distilling the sample with a volatile solvent and therefore this dehydrated material can not be used for other required tests. This method is equally accurate and is suitable for creosote, tar, petroleum and mixtures thereof.

A. Apparatus

110. General Description

The apparatus shall consist of a metal still or glass flask, heated by suitable means and provided with a reflux condenser discharging into a trap connected to the still or flask. The trap serves to collect and measure the condensed water and to return the solvent to the still.

111. Distilling Apparatus

The type of distilling apparatus used is not an essential feature of this method, but glass has been generally used for creosote and petroleum products and the metal still for road materials and tars.

(a) The metal still (Fig. 1405.1 A) shall be a vertical cylindrical vessel, preferably of copper, having a faced flange at the top to which the head is tightly attached by means of a clamp. The head shall be of metal, preferably of brass or copper, and be provided with a tabulation 1 inch in inside diameter.

(b) The glass flask (Fig. 1405.1 B) shall be of the short neck, round-bottom type, made of well-annealed glass, having an approximate capacity of 500 ml.

112. Burner

The burner used with the metal still shall be a ring gas burner 4 inch (100 mm.) in inside diameter. With the glass flask, an ordinary gas burner or electric heater may be used as a source of heat.

113. Condenser

The condenser shall be of the water-cooled, reflux, glass-tube type, having a condenser jacket not less than 400 mm. (15¾ inch) in length with an inner tube 12 to 16 mm. (½ to ⅝ inch) in diameter. The end of the condenser to be inserted in the trap shall be ground off at an angle of 60 degrees.

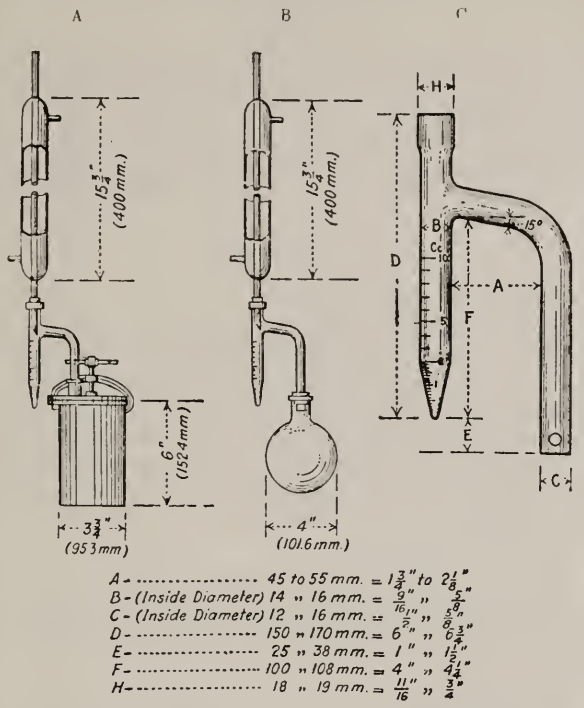

Fig. 1405.1.—Apparatus for Water Test, Method No. 2.

114. Trap

The trap shall be made of well-annealed glass constructed in accordance with Fig. 1405.1 C and shall be graduated as shown from 0 to 10 ml. in 0.1 ml. divisions. The error of any indicated capacity shall not be greater than 0.05 ml.

115. Solvent

(a) The solvent used when testing petroleum products or bituminous materials derived from petroleum shall be gasoline free from water and shall conform to the following distillation requirements determined in accordance with the Method of Test for Distillation of Gasoline, Naphtha, Kerosene, and Similar Petroleum Products (Serial Designation: D86–35) of the American Society for Testing Materials:

5 percent shall distill at a temperature not below 194 degrees F. (90 degrees C.) nor above 212 degrees F. (100 degrees C.).

90 percent shall distill below 410 degrees F. (210 degrees C.).

(b) The solvent used when testing bituminous materials derived from coal tar, water-gas tar, etc., shall be a coal tar naphtha or a light oil free from water and shall conform to the following distillation requirements, determined in accordance with the Method of Test for Distillation of Gasoline, Naphtha, Kerosene, and Similar Petroleum Products (Serial Designation: D86–35) of the American Society for Testing Materials:

98 percent shall distill between 248 degrees F. (120 degrees C.) and 482 degrees F. (250 degrees C.).

B. Sampling

116. Sample

The sample shall be thoroughly representative of the material to be tested and the portion of the sample used for the test shall be thoroughly representative of the sample itself. Deviation from this requirement shall not be permitted.

Note—The difficulties in obtaining proper representative samples for this determination are unusually great so that the importance of sampling cannot be too strongly emphasized.

C. Procedure

117. Dilution of Sample with Solvent

When the sample to be tested contains less than 10 percent of water, exactly 100 ml. of the material to be tested shall be placed into the still or flask and thoroughly mixed with an equal volume of solvent by swirling, proper care being taken to avoid any loss of material. If the material is measured by volume, an accurate 100 ml. graduated cylinder shall be used and the contents transferred to the still by rinsing with one 50-ml. portion of solvent followed by two successive 25-ml. portions of solvent, the cylinder being allowed to drain each time. When the sample to be tested contains more than 10 percent of water, the volume of material used shall be decreased to that which will yield somewhat less than 10 ml. of water.

Note—In special cases where the water content exceeds 10 percent and it is not desirable to reduce the size of the sample to that which will yield somewhat less than 10 ml. of water, a distilling tube receiver graduated from 0 to 25 ml. may be used. This tube shall be graduated from 0 to 2 ml. in 0.1 ml., from 2 to 5 ml. in 0.2 ml. and from 5 to 25 ml. in 0.5 ml.

118. Assembling Apparatus

The apparatus shall be assembled as shown in Fig. 1405.1 A and B. The connections between the still or flask, trap and condenser, shall be made by means of tight-fitting corks. When the metal still is used, a heavy paper gasket moistened with the solvent shall be inserted between the lid and flange before attaching the clamp.

119. Distillation

Heat shall then be applied and so regulated that the condensed distillate falls from the end of the condenser at the rate of from 2 to 5 drops per second. The ring burner used with the metal still should be placed about 3 inches above the bottom of the still at the beginning of the distillation and gradually lowered as the distillation proceeds.

The distillation shall be continued at the specified rate until no water is visible on any part of the apparatus except at the bottom of the trap. This operation usually requires less than an hour. A persistent ring of condensed water in the condenser tube shall be removed by increasing the rate of distillation for a few minutes.

120. Calculation

The volume of condensed water measured in the trap at room temperature multiplied by 100 and divided by the volume of the sample used shall be the percentage of water and shall be reported as ".....percent water by volume."

121. Accuracy

The accuracy to be expected with this method is that duplicate determinations of water should not differ from each other by more than one division on the trap.

Appendix B

TIES

rper, L. B. Holt,
ım, T. H. Strate,

s been revised to

ory covering the
n, Wis., and the

Engineering

					Average Life to 1–1–38
				)0	13.25
				)9	13.50
				17	12.90
				)0	13.52
				)0	12.88
				8	12.73
				0	19.72
				7	24.79
				0	23.04
				0	14.51
				3	24.48
				4	26.86
				5	25.49
				2	25.30
Newton, Kan., EB	1913	149	143	95.97	22.24
Texico-Lubbock, Tex.	1913	100,459	17,025	16.95	22.40
Walton, Kan.	1917	10,845	2,077	19.15	22.92
Turner-Holliday, Kan.	1918	5,806	2,657	45.76	19.52
Chilocco, Okla.	1919	10,268	2,167	21.10	17.60
Chilocco, Okla.	1919	3,262	351	10.76	16.51
					17.78

CROSS TIE RENEWALS PER MILE OF ALL TRACK MAINTAINED 1911-1940

COMMITTEE T-1 AREA A
END AREA

YEAR	AT&SF	B&O	C&A&G	C&EI	CCC&STL	CMStP&P	C&NW	D&LW	GT NORTHERN	ILL'S CENTRAL	K.C. SOU.	LEHIGH VALLEY	MICH. CENT.	MK&T	MONON C&L	NYC (EAST)	NYC (WEST)	NOR. PACIFIC	PENNA	SOUTHERN PAC.	TERMINAL RR. ASSN.	UNION PACIFIC	C.R.R. of N.J.	READING	BOSTON & MAINE	C&O.	NEW YORK CENTRAL	TOTALS FOR ALL ROADS
	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES TIES	MILES	NO OF TIES PER MILE
1911	8,432 2,112,776	3,148 775,747			932	1,783		1,214	2,773	1,396																	19,275	5,663,178
12	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
13	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
14	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
15	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
16	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
17	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
18	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
1919	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
20	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
21	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
22	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
23	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
24	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
1925	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
26	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
27	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
28	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
29	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
1930	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
31	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
32	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
33	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
34	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
1935	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
36	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
37	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
38	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
39	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749
1940	8,483 2,112,776	3,158 819,384			972 238,338	1,945		1,214	2,773	1,396																	19,735	5,782,749

① MAIN LINE ONLY

② INCLUDED IN N.Y.N.H. & H. (CENTRAL)

Appendix B

(2) SERVICE TEST RECORDS FOR TREATED TIES

W. R. Goodwin, Chairman, Subcommittee; G. B. Campbell, L. H. Harper, L. B. Holt, R. S. Hubley, R. P. Hughes, Edward Kelly, W. S. King, A J. Loom, T. H. Strate, W. A. Summerhays.

The table of tie renewals per mile maintained on various roads has been revised to include data for 1937.

Reports of special test tracks are submitted on the following roads:

Atchison, Topeka & Santa Fe
Baltimore & Ohio
Chicago, Burlington & Quincy
Chicago, Milwaukee, St. Paul & Pacific

(Inspection reports are submitted by The Forest Products Laboratory covering the installation in the Fair Grounds and University test sections at Madison, Wis., and the Hartford, Wis., test section.)

Chicago & North Western
Canadian National Railways
Northern Pacific
Southern Pacific.

The above is offered as a progress report.

ATCHISON, TOPEKA & SANTA FE RAILWAY

Statement Showing Various Special Tests for The American Railway Engineering Association as of January 1, 1938

Station	*Year Inserted*	*Original No. Inserted*	*Total Ties Removed*	*Percent Ties Removed from Track*	*Average Life to 1-1-38*
Hewn Southern Yellow Pine, Zinc Chloride					
Newton, Kan., EB	1904	6,357	6,357	100.00	13.25
Newton, Kan., EB	1905	9,251	9,250	99.99	13.50
Turner-Holliday, Kan.	1918	4,638	4,261	91.87	12.90
Sawn Southern Yellow Pine, Zinc Chloride					
Newton, Kan., EB	1904	2.517	2,517	100.00	13.52
Newton, Kan., EB	1905	40	40	100.00	12.88
Turner-Holliday, Kan.	1918	673	580	86.18	12.73
Hewn Southern Yellow Pine, Creosote					
Clements, Kan.	1904	165	165	100.00	19.72
Ponca City, Okla.	1904	190	189	99.47	24.79
Perry, Okla.	1904	27	27	100.00	23.04
Marceline, Mo.	1905	304	304	100.00	14.51
Melvern, Kan.	1906	24,224	22,984	94.88	24.48
Mission-Hutchinson	1909	106	100	94.34	26.86
St. John-Sylvia, Kan.	1910	40,867	16,536	40.46	25.49
Lewis, Kan.	1910	13,636	6,684	49.02	25.30
Justiceburg, Tex.	1911	1,460	711	48.70	22.24
Newton, Kan., EB	1913	149	143	95.97	22.40
Texico-Lubbock, Tex.	1913	100,459	17,025	16.95	22.92
Walton, Kan.	1917	10,845	2,077	19.15	19.52
Turner-Holliday, Kan.	1918	5,806	2,657	45.76	17.60
Chilocco, Okla.	1919	10,268	2,167	21.10	16.51
Chilocco, Okla.	1919	3,262	351	10.76	17.78

Atchison, Topeka & Santa Fe Statement—Continued

Station	Year Inserted	Original No. Inserted	Total Ties Removed	Percent Ties Removed from Track	Average Life to 1-1-38
Sawn Southern Yellow Pine, Creosote					
Marland, Okla.	1904	275	273	99.27	21.51
Perry, Okla.	1904	348	345	99.14	22.74
Garnett, Kan.	1905	383	373	97.39	19.81
Argonia, Kan.	1905	572	548	95.80	16.76
Mission-Hutchinson	1909	69	60	86.96	22.23
St. John-Sylvia, Kan.	1910	9,564	6,489	67.85	21.97
Texico-Lubbock, Tex.	1913	161,699	28,878	17.86	22.99
Newton, Kan., EB	1913	151	112	74.17	23.25
Walton, Kan.	1917	1,362	148	10.87	19.72
Turner-Holliday, Kan.	1918	994	360	36.22	17.93
Sawn Southern Yellow Sap Pine, Creosote					
Justiceburg, Tex.	1911	376	329	87.50	17.10
Sawn Southern Yellow Heart Pine, Creosote					
Justiceburg, Tex.	1911	374	30	8.02	25.43
Hewn White Oak, Creosote					
Justiceburg, Tex.	1911	375	250	66.67	23.55
Hewn Red Oak, Creosote					
Justiceburg, Tex.	1911	225	111	49.33	23.91
Texico-Lubbock, Tex.	1913	171	36	21.05	22.79
Newton, Kan.	1913	150	124	82.67	23.60
Walton, Kan.	1917	4,347	435	10.01	19.65
Turner-Holliday, Kan.	1918	2,769	151	5.45	18.87
Sawn Red Oak, Creosote					
Plevna, Kan.	1907	52	51	98.08	15.87
Justiceburg, Tex.	1911	281	128	45.55	21.62
Hewn Gum, Creosote					
St. John-Sylvia, Kan.	1909	1,329	80	6.02	27.78
St. John-Sylvia, Kan.	1910	13,072	750	5.74	26.87
Justiceburg, Tex.	1911	362	96	26.52	24.04
Sawn Gum, Creosote					
Hutchinson, Kan.	1907	392	361	92.09	24.02
Hutchinson, Kan., M.L.	1907	230	186	80.87	23.53
Plevna, Kan.	1907	262	248	94.66	21.26
Justiceburg, Tex.	1911	338	188	55.62	21.28
Newton, Kan.	1913	147	116	78.91	22.10
Chillicothe, Ill.	1926	330	None	0.00	11.00
Sawn Douglas Fir, Creosote					
Barstow, Cal.	1910	12,910	12,469	96.59	16.74
Sawn Beech, Creosote					
Justiceburg, Tex.	1911	307	99	32.25	23.09
Smithshire, Ill.	1912	386	255	66.06	23.74
Marceline, Mo.	1912	99	32	32.32	24.40
Tecumseh, Kan.	1912	161	161	100.00	16.52
Newton, Kan.	1912	157	124	78.98	23.80
Hewn Engelmann Spruce, Creosote					
Pinta, Ariz.	1928	858	None	0.00	9.00
Sawn Engelmann Spruce, Creosote					
Pinta, Ariz.	1928	1,031	None	0.00	9.00
Sawn Western Yellow Pine, 50% Creosote 50% Petroleum					
Texico-Lubbock, Tex.	1913	8,259	270	3.27	23.70

ATCHISON, TOPEKA & SANTA FE STATEMENT—Continued

Station	Year Inserted	Original No. Inserted	Total Ties Removed	Percent Ties Removed from Track	Average Life to 1-1-38
HEWN SOUTHERN YELLOW PINE, 7-LB. MIXTURE 70% CREOSOTE 30% PETROLEUM					
Mission-Hutchinson, Kan.	1923	27,603	131	0.47	13.99
Saffordville, Kan.	1923	12,917	637	4.93	13.95
Saffordville, Kan.	1924	107	None	0.00	13.00
Mission-Hutchinson, Kan.	1925	54	None	0.00	12.00
SAWN SOUTHERN YELLOW PINE, 7-LB. MIXTURE 70% CREOSOTE 30% PETROLEUM					
Mission-Hutchinson, Kan.	1923	11,791	46	0.39	14.00
SAWN RED OAK, 7-LB. MIXTURE 70% CREOSOTE 30% PETROLEUM					
Mission-Hutchinson, Kan.	1923	1,042	143	13.72	13.86
HEWN GUM, 7-LB. MIXTURE 70% CREOSOTE 30% PETROLEUM					
Saffordville, Kan.	1924	152	1	0.66	13.00
SAWN GUM, 7-LB. MIXTURE 70% CREOSOTE 30% PETROLEUM					
Saffordville, Kan.	1923	2,766	89	3.22	13.98
Saffordville, Kan.	1924	145	None	0.00	13.00
Chillicothe, Ill.	1926	329	None	0.00	11.00
HEWN SOUTHERN YELLOW PINE, 8-LB. MIXTURE 70% CREOSOTE COAL-TAR SOLUTION 30% PETROLEUM					
Chillicothe, Ill.	1925	2,104	None	0.00	12.00
Chillicothe, Ill.	1926	2,421	None	0.00	11.00
HEWN COTTONWOOD, 5 LB. CREOSOTE					
Lucy, N. M.	1923	75	None	0.00	14.00
SAWN COTTONWOOD, 5 LB. CREOSOTE					
Lucy, N. M.	1923	75	2	2.67	13.81
HEWN COTTONWOOD, 7-LB. MIXTURE 50% CREOSOTE 50% PETROLEUM					
Lucy, N. M.	1923	75	None	0.00	14.00
SAWN COTTONWOOD, 7-LB. MIXTURE 50% CREOSOTE 50% PETROLEUM					
Lucy, N. M.	1923	75	None	0.00	14.00
HEWN SOUTHERN YELLOW PINE, 8-LB. MIXTURE 50% CREOSOTE 50% PETROLEUM					
Saffordville, Kan.	1924	8,300	22	0.27	13.00
Mission-Hutchinson, Kan.	1928	363	None	0.00	9.00
Mission-Hutchinson, Kan.	1929	26,697	23	0.09	8.00
Mission-Hutchinson, Kan.	1930	131	None	0.00	7.00
SAWN SOUTHERN YELLOW PINE, 8-LB. MIXTURE 50% CREOSOTE 50% PETROLEUM					
Mission-Hutchinson, Kan.	1927	24	None	0.00	10.00
Mission-Hutchinson, Kan.	1928	3,181	None	0.00	9.00
Mission-Hutchinson, Kan.	1929	5,894	None	0.00	8.00
SAWN GUM, 8-LB. MIXTURE 50% CREOSOTE 50% PETROLEUM					
Saffordville, Kan	1924	141	1	0.71	12.97
SAWN WESTERN YELLOW PINE, 8-LB. MIXTURE 45% CREOSOTE 55% PETROLEUM					
Pinta, Ariz.	1928	2,267	6	0.27	8.99
SAWN WESTERN YELLOW PINE, 8-LB. MIXTURE 45% CREOSOTE 55% PETROLEUM, STEAMED 2 HOURS, 20 LB.					
Pinta, Ariz.	1928	439	None	0.00	9.00
SAWN WESTERN YELLOW PINE, 8-LB. MIXTURE 45% CREOSOTE 55% PETROLEUM, STEAMED 2 HOURS, 30 LB.					
Pinta, Ariz.	1928	451	None	0.00	9.00

ATCHISON, TOPEKA & SANTA FE STATEMENT—Continued

Station	Year Inserted	Original No. Inserted	Total Ties Removed	Percent Ties Removed from Track	Average Life to 1-1-38
HEWN SOUTHERN YELLOW PINE, 8-LB. MIXTURE 45% CREOSOTE 55% PETROLEUM					
Pinta, Ariz.	1928	1,853	None	0.00	9.00
HEWN ENGELMANN SPRUCE, 8-LB. MIXTURE 45% CREOSOTE 55% PETROLEUM					
Pinta, Ariz.	1928	934	None	0.00	9.00
SAWN ENGELMANN SPRUCE, 8-LB. MIXTURE 45% CREOSOTE 55% PETROLEUM					
Pinta, Ariz.	1928	1,210	None	0.00	9.00
HEWN WESTERN YELLOW PINE, 8-LB. MIXTURE 25% CREOSOTE 75% PETROLEUM					
Acomita, N. M.	1924	998	2	0.20	12.99
HEWN SOUTHERN YELLOW PINE, 8-LB. MIXTURE 25% CREOSOTE 75% PETROLEUM					
Acomita, N. M.	1924	999	2	0.20	13.00
Whiteface, Tex.	1925	558	None	0.00	12.00
Boise City, Okla.	1925	500	None	0.00	12.00
HEWN GUM, 8-LB. MIXTURE 25% CREOSOTE 75% PETROLEUM					
Boise City, Okla.	1925	253	None	0.00	12.00
Whiteface, Tex.	1925	254	None	0.00	12.00
SAWN WESTERN YELLOW PINE, 8-LB. MIXTURE 25% CREOSOTE 75% PETROLEUM					
Pinta, Ariz.	1928	503	None	0.00	9.00
SAWN WESTERN YELLOW PINE, 8-LB. MIXTURE 25% CREOSOTE 75% PETROLEUM, STEAMED 2 HOURS, 20 LB.					
Pinta, Ariz.	1928	447	None	0.00	9.00
SAWN WESTERN YELLOW PINE, 8-LB. MIXTURE 25% CREOSOTE 75% PETROLEUM, STEAMED 2 HOURS, 30 LB.					
Pinta, Ariz.	1928	456	None	0.00	9.00
HEWN OHIA, UNTREATED					
Stafford, Kan.	1910	132	128	96.97	19.64
SAWN OHIA, UNTREATED					
Stafford, Kan.	1910	108	105	97.22	20.84

THE BALTIMORE AND OHIO RAILROAD

Herring Run Tie Test, Annual Report—1937, End of 23 Years' Service

Introductory

The Herring Run test tie section is located in the eastward main track at Herring Run, Md., on the Baltimore division, about seven miles east of Baltimore, Md. Eighty-five percent of the test was installed in November, 1914, and the remainder in August, 1915, in co-operation with the Forest Service of the United States Department of Agriculture.

The development to date, as set forth in the accompanying report, indicates the total service life of the untreated ties and the trend of what is to be expected in service life from the treated.

Purpose of Test

The purpose of the Herring Run test is to determine the economic value of various kinds of preservative treatments, and incidentally, to note the life of red oak treated ties compared with red oak ties untreated.

Conditions of Test

(1) *Time*—All ties in the test except those in Section 14 were installed in November, 1914. Section 14 was placed in August, 1915. The test, therefore, is now completing its twenty-third year.

(2) *Traffic*—An average of 16,560,000 gross tons per year has been handled over this track.

(3) *Rainfall*—The average annual rainfall has been 41.8 inches. This is, no doubt, sufficient to have caused leaching of soluble preservatives.

(4) *Temperature*—Mean average, January, 35.3 deg. F., mean average, July, 77.8 deg. F. Extremes, 7.9 deg. F. to 99.7 deg. F.

(5) *Maintenance*—Maintenance conditions have been uniform over the entire test. Track on entire test raised and ties respaced for 39-ft. rails during summer of 1926. Track from tie 0 to tie 1916 is pick-tamped, from tie 1916 to east end of test, machine-tamped. Track on entire test raised in 1929, 1933, and 1936 and machine-tamped.

Derailments

Four derailments have occurred within the limits of the test, damaging 2,473 ties, or 70 percent of the total. Of this number, 121 were so badly damaged that they were removed from track. The destructive effect of these derailments on the remainder will be given consideration when the ties are removed. There have also been 118 ties removed account switch installations.

The indications are that the life of many ties in this test has been and will continue to be materially reduced as a result of decay starting in the crushed fibers of the wood marked by derailed wheels. Attention is directed to the fact that all groups in the test, excepting Section 5 of the straight creosote group, have suffered more or less from wheel marks at various times. For this reason the test still retains an important value as a basis for a comparison of the effectiveness of the various methods of treatment, although any conclusions regarding the average life of ties so treated must be drawn with a proper regard for the damage resulting from these derailments.

RESULTS OF TEST—RED OAK TIES, 22 YEARS' SERVICE

Sec. No.	Tie Numbers	TREATMENT		Ties Placed	Ties in Test	Removed To Date		Average life to date of ties in test
		Process	Per Cu. Ft.			No.	Per Cent	
				Note	Note			
1	3— 300	Untreated		298	289	289	100.0	5.1
2	301— 600	Burnettizing	0.35 lb. Zinc Chl.	300	161	160	99.4	12.7
3	601— 900	Burnettizing	0.63 lb. Zinc Chl.	300	211	192	91.0	15.2
4	901—1200	Straight Cr.	4.02 lb. Creosote	300	300	283	95.5	16.5
5	1201—1500	Straight Cr.	9.78 lb. Creosote	300	300	184	62.0	21.1
6	1501—1650	W. G. Tar Straight Cr.	5.16 lb. WG Tar Cr.	150	150	135	90.0	17.3
7	1651—1800	W. G. Tar Straight Cr.	6.12 lb. WG Tar. Cr.	150	150	135	90.0	17.5
8	1801—1950	W. G. Tar Straight Cr.	7.09 lb. WG Tar Cr.	150	150	134	89.4	15.4
9	1951—2100	W. G. Tar Straight Cr.	10.90 lb. WG Tar Cr.	150	150	129	87.3	16.7
10	0–212 Cull	W. G. Tar Straight Cr.	11.00 lb. WG Tar Cr.	212	211	184	87.3	15.2
11	2101—2400	Sodium Fluoride	0.41 lb. Sodium Fluoride	300	300	300	100.0	14.5
12	2401—2700	Card	0.63 lb. Zinc Chlr. 0.76 lb. Creosote. 0.69 lb. Zinc Chlr 1.35 lb. WG Tar Cr.	300	300	298	99.4	13.2
13	2701—3000	Card	0.37 lb. Creosote	300	300	278	92.7	16.0
14	3001—3300	Card	0.5 lb. Zinc Chlr., 2.0 lb. Creosote*	300	288	285*	99.0	13.1

Note: The difference between "Ties Placed" and "Ties in Test" is due to elimination from test of ties replaced because of derailments and installation of switches.
* This group installed 9 months (0.75 year) after other ties in this test.

Average Life

The number and percent renewals of the untreated and the different groups of treated ties with the average life to date of all ties are given in the table.

Conclusions

Sufficient data are provided from the renewals to date in five of the groups to substantiate the following conclusions as to the service life that will be secured:

All Ties—Red Oak

	Average Life Years
Untreated	5.0
Treated—	
Burnettizing	
0.35-lb. Zinc Chloride	12.7
Sodium Fluoride	
0.41-lb. Sodium Fluoride	14.5
Card	
0.64-lb. Zinc Chloride—0.76-lb. Creosote	13.2
Card	
0.50-lb. Zinc Chloride—2.00-lb. Creosote	13.1

Germantown–Barnesville Test

At the Germantown–Barnesville test, the last report of which was made in 1930, no ties have been removed. As stated in the record referred to above, there are 20 different groups in this test. The condition of the ties, as disclosed in the 1937 inspection, is as follows:

Group	*Preservative*	*Red Oak*	*White Oak*	*Mixed*
1	Creosote	Good	Good	Excellent
2	Creosote	Checked	Good	Excellent
3	Water Gas Tar	Good	Good	Some checks and splits
4	Creosote—Petroleum	Good	Good	Good
5	Creosote—Petroleum	Excellent	Good	Good
6	Creosote—Petroleum	Good		
7	Creosote—Coal Tar	Good	Good	Good
8	Creosote—Coal Tar	Good	Good	Good
9	Creosote—Coal Tar	Good	Fair splits	Fair checks
10	Creosote—Coal Tar	Good—some checks	Good	Excellent
11	Creosote—W. G. Tar	Good	Good	Good
12	Creosote—W. G. Tar	Some checks	Good	Good
13	Creosote—W. G. Tar	Good	Excellent	Excellent
14	Creosote—Pet.—W. G. Tar	Fair	Good	Some splits
15	Creosote—Pet.—W. G. Tar	Good	Fair checks	Good
16	Creosote—Pet.—W. G. Tar	Good	Good—some checks	Good
17	Zinc—Petroleum	Splits and decay		
18	Zinc—Petroleum	Considerable decay		
19	Zinc—Petroleum		Considerable decay	
20	Experimental—Various			

Windsor–Blanchester Test Ties, Report for Year 1937, 27 Years' Service

History of Test

The Windsor-Blanchester tie test section is located in the westward main track one mile west of Blanchester, Ohio, on the Ohio division.

The ties were placed March 1911. As the renewals for the period ending March, 1938, had been completed when the recent inspection was made, this report covers 27 years of service.

The tables below describe the kinds of ties, methods of treatment, and conditions of service.

Purpose of Test

(1) To determine the value of various kinds of preservative treatments compared with the untreated white oak tie.

(2) To determine the value of red oak treated ties compared with treated ties of other woods (gum, beech, maple, elm, etc.).

Conditions of Test

Age—Test ties were placed March 1911. Renewals for period to March 1938 are complete. This report, therefore, covers 27 years' service.

Traffic—Average gross tons per year 4,988,000

Climate—Average annual rainfall is 41.2 inches.

Temperature range—average 27 years.

High ..... 96.3 deg. F.

Low ..... 5.9 deg. F.

Maintenance—Maintenance conditions have been uniform for all ties in the test and are normal for main line tracks in gravel ballast territory.

Derailments

Two derailments have occurred within the limits of this test. The first was in 1913 and was confined to the Timber Asphalt Group. Fifteen ties were damaged to the extent that it was necessary to remove them from track and eliminate them from the test.

The second derailment occurred in January, 1929, and damaging 588 ties in the Straight Creosote Red Oak Group and 204 in the Card Process Other Woods Group. Fifty-three red oaks and thirteen "other woods" were so badly damaged that they were removed from track and eliminated from the test. The average life of the other damaged ties will be reduced as a result of the fibers of the wood being crushed, which will make them more susceptible to decay.

The following statement gives the ties damaged:

Treatment and Kind of Wood	*Ties Placed*	*Ties Damaged*
(January 4, 1929) Straight Creosote		
Red Oak	873	584
Other Woods	252	4
(January 4, 1929) Card Process		
Other Woods	1219	204
(1913) Timber Asphalt		
Rek Oak	1001	102

Average Life

The average life to date for the different woods in the various groups is given in the following statement:

Age of Tie Test—27 Years

Treatment and Kind of Wood	*Ties Placed* Note	*Ties in Test* Note	*Removed to date No.*	*Percent*	*Average Life to Date of Ties in Test*
Untreated					
White Oak	757	757	751	99.2	10.2
Straight Creosote					
Red Oak	873	820	231	28.2	25.5
*Other Woods	252	252	130	51.5	20.6
Card Process					
Red Oak	1125	1125	765	68.0	21.5
*Other Woods	1219	1206	882	73.1	18.8
Timber Asphalt					
Red Oak	984	969	965	99.6	10.7

Note: The difference between "Ties Placed" and "Ties in Test" is due to elimination from test of ties account of removals from derailments.

* Other Woods—Beech, Hard Maple, Gum and Elm.

Conclusions

Sufficient data are provided from the renewals to date in two of the groups to substantiate the following conclusions as to the service life that will be secured:

	Average Life Years
Untreated	
White Oak	10
Treated	
Timber Asphalt—	
A non-toxic oil treatment without pressure	
Red Oak	11

In the other groups, the average life to date and the percentage of ties remaining in track after 27 years service, provide a tentative basis for the presentation of the following probable service life that will be secured—

Treated Ties	*Average Life to Date Years*	*Percentage Of Ties Still In Track*	*Probable Average Life Years*
Straight Creosote—			
Red Oaks	25.5	71.8	29
Other Woods	20.6	48.4	24
Card Process—			
Red Oaks	21.5	32.0	23
Other Woods	18.8	26.9	20

CHICAGO, BURLINGTON & QUINCY RAILROAD

Report of Twenty-Eighth Annual Inspection of Experimental Ties

The results of the 1937 inspection of the experimental ties in the tracks of the Chicago, Burlington & Quincy Railroad are given in the accompanying tabulations. These ties were laid in 1909 and 1910, some treated with coal-tar creosote by the full-cell process, with 10 to 12 lb. per cubic foot; some with zinc chloride (Burnett process) with ½ lb. per cubic foot; some with a mixture of these two preservatives (Card process), with an absorption of ½ lb. of zinc chloride and 3 lb. of creosote per cubic foot; and some were untreated:

Average Life of Untreated Ties in Years

Cottonwood	2.9	Red gum	4.1	Tamarack	5.1	Hickory	5.5
Sycamore	3.3	Hard maple	4.7	Loblolly pine	5.3	Pin oak	6.3
Tupelo gum	3.5	Hemlock	4.9	Poplar	5.3	Cypress	8.3
Red birch	3.6	Beech	5.0	Red oak	5.3	Chestnut	9.7
Soft maple	3.6	Ash	5.1	White elm	5.3	White oak	11.1

Summary of 1937 Inspection of Crosstie Test Tracks, Results of 28 Years' Service

Process	Lines East					Lines West				
	Total placed	*Total removed to date*	*Percent removed account decay*	*Percent removed account other causes*	*Estimated years average life*	*Total placed*	*Total removed to date*	*Percent removed account decay*	*Percent removed account other causes*	*Estimated years average life*
Creosote	2,046	1,276	21	42	28.0	1,236	788	16	48	27.5
Card	10,241	9,002	32	56	23.0	5,591	5,034	33	57	22 5
Burnett	1,578	1,552	54	44	16.1*	910	902	49	50	14 9*
Untreated	2,046	2,045	89	10	5.4*	1,226	1,226	91	9	5.8*

Note: These percentages include only the ties placed in what are termed the 1,000 tie lots on the various divisions.
* Actual average years life to date.

1937 Inspection of Crosstie Test Track, C., B. & Q. R. R.—Results of 28 Years' Service

Process	Lines East						Lines West					
	Total placed	Total removed to date	Percent removed account decay	Percent removed account other causes	Estimated years average life	Actual years average life to date	Total placed	Total removed to date	Percent removed account decay	Percent removed account other causes	Estimated years average life	Actual years average life to date
Ash Ties												
Creosote	19	19	32	68		16.7	15	13	20	67	23.0	20.3
Card	289	270	19	74		18.7	103	94	22	69		18.1
Burnett	16	16	44	56		18.3	15	15	47	53		17.2
Untreated	70	70	99	1		5.1	46	46	100			5.3
Beech Ties												
Creosote	321	117	10	27	32.5	25.3	163	62	9	29	32.5	24.6
Card	807	770	44	51		17.6	418	396	41	54		17.2
Burnett	210	207	55	43		16.0	105	102	57	40		15.8
Untreated	134	134	98	2		4.6	74	74	93	7		5.4
Birch Ties												
Creosote	75	69	65	27		22.7	59	41	15	54	26.5	22.2
Card	715	651	39	52		18.0	360	338	34	60		18.0
Burnett	73	73	48	52		13.0	30	30	43	57		14.4
Untreated	139	139	99	1		3.6	78	78	100			3.6
Chestnut Ties												
Creosote												
Card	164	164	18	82		10.1	89	89	9	91		10.2
Burnett												
Untreated	169	169	28	72		9.4	90	90	22	78		10.2
Cottonwood Ties												
Creosote	88	43	5	44	30.0	24.7	45	17	16	22	32.5	23.4
Card	296	242	29	53	24.5	19.2	160	137	26	60	23.5	17.9
Burnett												
Untreated	56	56	95	5		2.6	30	30	100			3.5
Cypress Ties												
Creosote	25	15	4	56	28.0	25.6	29	27	41	52	22.0	19.7
Card	409	350	11	75	23.5	19.4	254	230	25	65	22.5	18.3
Burnett	25	25	12	88		21.6	30	30	50	50		14.7
Untreated	135	134	78	21		8.8	90	90	89	11		7.5

1937 Inspection of Crosstie Test Track, C., B. & Q. R. R.—Results of 28 Years' Service—Continued

Process	Lines East						Lines West					
	Total placed	Total removed to date	Percent removed account decay	Percent removed account other causes	Estimated years average life	Actual years average life to date	Total placed	Total removed to date	Percent removed account decay	Percent removed account other causes	Estimated years average life	Actual years average life to date
Pin Oak Ties												
Creosote	189	83	4	40	31.0	24.9	133	73	8	47	29.0	24.4
Card	512	428	24	60	24.0	21.5	321	291	26	64	22.5	19.6
Burnett	23	20	52	35	23.0	22.4	44	44	32	68	----------	15.9
Untreated	81	81	96	4	----------	6.4	45	45	98	2	----------	6.2
Poplar Ties												
Creosote	50	36	18	54	26.0	23.4	30	27	17	73	22.5	17.2
Card	396	382	43	54	----------	15.4	253	242	43	52	----------	15.4
Burnett	50	50	44	56	----------	14.3	30	30	57	43	----------	13.0
Untreated	81	81	94	6	----------	5.1	45	45	96	4	----------	5.6
Red Gum Ties												
Creosote	89	64	32	40	26.0	20.5	48	33	27	42	26.5	18.8
Card	429	360	40	44	24.0	19.2	233	182	43	35	25.0	19.8
Burnett	75	74	66	33	----------	11.6	43	43	74	26	----------	12.4
Untreated	98	98	97	3	----------	3.8	54	54	98	2	----------	4.6
Sycamore Ties												
Creosote	75	46	37	24	28.0	23.6	15	4	----------	27	35.0	25.4
Card	399	322	50	31	24.5	19.5	121	114	64	30	----------	14.6
Burnett	75	75	71	29	----------	13.7	15	15	80	20	----------	13.5
Untreated	81	81	98	2	----------	2.9	50	50	96	4	----------	3.9
Tamarack Ties												
Creosote	106	89	11	73	24.0	21.3	108	90	14	69	24.0	19.0
Card	813	788	21	76	----------	18.1	494	459	33	61	----------	17.4
Burnett	108	104	41	96	----------	18.1	107	105	31	67	----------	16.0
Untreated	98	98	96	4	----------	4.9	77	77	99	1	----------	5.3
Tupelo Gum Ties												
Creosote	99	65	22	43	27.0	21.6	54	35	22	43	27.0	20.4
Card	436	287	20	45	27.0	22.0	237	127	26	28	29.0	24.0
Burnett	76	75	47	51	----------	15.2	41	41	61	39	----------	14.0
Untreated	88	88	98	2	----------	3.0	48	48	98	2	----------	4.4

Elm Ties												
Creosote	208	127	28	33	28.0	23.8	119	52	10	34	31.0	23.7
Card	594	469	28	51	25.0	20.9	371	295	30	50	24.5	20.3
Burnett	224	217	49	48	----------	18.8	73	72	62	37	----------	16.1
Untreated	113	113	91	9	----------	4.8	78	78	96	4	----------	5.9
Hemlock Ties												
Creosote	136	116	29	55	24.0	19.8	99	84	22	63	23.5	18.7
Card	816	759	29	64	----------	18.2	488	471	39	56	----------	15.8
Burnett	125	121	47	50	20.0	17.2	87	86	41	57	----------	15.5
Untreated	112	112	100	----------	----------	4.7	78	78	99	1	----------	15.3
Hickory Ties												
Creosote	10	7	10	60	26.5	24.4	15	11	13	60	26.0	21.3
Card	185	180	31	66	----------	16.3	105	102	43	54	----------	15.9
Burnett	9	8	22	67	23.0	21.4	15	15	53	47	----------	17.3
Untreated	65	65	89	11	----------	5.5	45	45	100	----------	----------	5.5
Pine Ties—Loblolly Sap												
Creosote	145	96	9	57	27.0	23.4	72	53	19	54	26.0	18.5
Card	949	793	29	54	24.0	19.4	386	353	25	66	----------	15.6
Burnett	128	128	74	26	----------	12.3	72	72	46	54	----------	12.0
Untreated	157	157	99	1	----------	5.5	91	91	100	----------	----------	4.8
Hard Maple Ties												
Creosote	82	58	46	24	26.5	24.0	34	22	15	50	27.0	22.4
Card	560	444	40	39	25.0	20.5	272	251	36	56	22.0	19.1
Burnett	50	49	50	48	----------	19.6	15	15	87	13	----------	16.7
Untreated	77	77	98	2	----------	4.3	45	45	100	----------	----------	5.3
Soft Maple Ties												
Creosote	139	120	44	42	23.5	19.5	63	41	29	37	27.0	21.6
Card	462	413	48	42	22.5	17.1	264	228	29	58	23.0	18.7
Burnett	125	125	64	36	----------	13.4	57	57	39	61	----------	13.6
Untreated	82	82	99	1	----------	3.4	43	43	95	5	----------	4.0
White Oak Ties												
Creosote	25	15	12	48	28.0	26.1	15	14	27	67	----------[3]	19.4
Card	234	230	39	59	----------	17.2	152	148	31	66	----------	18.0
Burnett	28	28	60	40	----------	17.4	15	15	40	60	----------	15.3
Untreated	81	81	88	12	----------	10.8	44	44	81	19	----------	11.7
Red Oak Ties												
Creosote	165	92	5	50	29.0	24.4	120	89	13	62	25.5	22.1
Card	776	699	25	65	22.5	19.9	510	497	34	64	----------	17.4
Burnett	158	157	56	44	----------	17.2	116	115	47	52	----------	15.3
Untreated	129	129	96	4	----------	5.1	75	75	93	7	----------	5.7

Condition of the Experimental Ties in the University Avenue Test Track of the Chicago, Milwaukee, St. Paul and Pacific Railway at Madison, Wisconsin, at an Inspection in September, 1938.

Preservative	Treating method[a]	Species	Form[b] of ties	Average absorption of preservative	Ties in Test	Good		Partly & Badly split & Defects other than decay		Decaying		Removed: Mainly for decay		Removed: Causes other than decay & Unknown causes		Not inspected (under crossings)	
				Lbs. per Cu. Ft.	No.	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ties set 1922 - 16 years service																	
Azol	F	Red oak	S	16.38[d]	95	-	-	-	-	3	3.2	87	91.6	-	-	5	5.2
Zinc chloride (high iron content)	F	Red oak	S	.58[e]	87	-	-	4	4.6	6	6.9	30	34.5	47	54.0	-	-
Ties set 1923 - 15 years service																	
25% low temp.c.t. distillate	F	Red oak	H	8.22	100[f]	35	35.0	53	53.0	10	10.0	-	-	-	-	2	2.0
75% mid continent oil																	
50% low temp.c.t. distillate	F	Red oak	H	9.24	99[f]	56	56.6	36	36.4	3	3.0	-	-	2	2.0	2	2.0
50% mid continent oil																	
Ties set 1924 - 14 years service																	
C.T. creosote, grade 1[h]	F	Red oak	H-S	14.60	16	3	18.7	12	75.0	-	-	-	-	1	6.3	-	-
Low temp.C.T. distillate	F	Red oak	H-S	8.94	86	26	30.2	46	53.5	4	4.7	2	2.3	8	9.3	-	-
10% low temp.c.t. distillate	F	Red oak	H-S	8.94	99	53	53.5	34	34.3	6	6.1	-	-	6	6.1	-	-
90% topped Cal. oil																	
25% low temp.c.t. distillate	F	Red oak	H-S	8.28	100	24	24.0	53	53.0	9	9.0	7	7.0	7	7.0	-	-
75% topped Cal. oil																	
Ties set 1925 - 13 years service																	
Basilit	F	Red oak	H-S	.28[e]	49	28	57.1	10	20.4	5	10.2	2	4.1	4	8.2	-	-
10% c.t. creosote, grade 1[h]	F	E. hemlock	S	10.26	87	36	41.4	23	26.4	16	18.5	3	3.4	9	10.3	-	-
90% petroleum																	
50% c.t. creosote, grade 1[h]	F	E. hemlock	S	11.91	81	45	55.6	23	28.4	7	8.6	2	2.5	4	4.9	-	-
50% petroleum																	
Sodium fluoride	F	Red oak	H-S	.52[e]	50	18	36.0	9	18.0	18	36.0	1	2.0	4	8.0	-	-
Sodium fluoride	F	Red oak	H-S	.26[e]	50	21	42.0	6	12.0	11	22.0	4	8.0	8	16.0	-	-
Triolith	F	Red oak	H-S	.25[e]	50	35	70.0	5	10.0	3	6.0	2	4.0	5	10.0	-	-
Zinc chloride	F	Red oak	H-S	.52[e]	50	12	24.0	6	12.0	16	32.0	10	20.0	6	12.0	-	-
Zinc chloride	F	Red oak	H-S	.26[e]	50	12	24.0	6	12.0	19	38.0	7	14.0	6	12.0	-	-
Zinc chloride	E	Red oak	H	.34[e]	49	3	6.1	12	24.5	23	46.9	5	10.2	6	12.3	-	-
Petroleum emulsion				4.87[i]													
Zinc chloride	E	So.yel.pine	H	.69[e]	42	16	38.1	18	42.9	1	2.4	-	-	7	16.7	-	-
Petroleum emulsion				9.21[i]													
Zinc chloride	E	So.yel.pine	H	.39[e]	49	17	34.7	30	61.3	1	2.0	-	-	1	2.0	-	-
Petroleum emulsion				7.92[i]													
Zinc chloride	E	So.yel.pine	H	.27[e]	47	16	38.3	21	44.7	4	8.5	1	2.1	3	6.4	-	-
Petroleum emulsion				9.34[i]													
Ties set 1926 - 12 years service																	
Basilit	F	Red oak	H-S	.52[e]	49	26	53.0	6	12.2	11	22.5	2	4.1	4	8.2	-	-
Basilit	F	E. hemlock	S	.18[e]	44	4	9.1	18	40.9	6	13.7	2	4.5	13	29.5	1	2.3
Sodium fluoride	F	E. hemlock	S	.17[e]	49	7	14.3	4	8.1	17	34.7	5	10.2	16	32.7	-	-
Triolith	F	Red oak	H-S	.56[e]	50	23	46.0	7	14.0	13	26.0	3	6.0	4	8.0	-	-
Triolith	F	E.hemlock	S	.18[e]	48	9	16.7	13	27.1	10	20.8	2	4.2	14	29.2	-	-

Condition of the Experimental Ties in the University Avenue Test Track of the Chicago, Milwaukee, St. Paul and Pacific Railway at Madison, Wisconsin, at an inspection in September, 1938. - (Continued)

Preservative	Treating method[a]	Species	Form of ties	Average absorption of preservative[b]	Ties in Test	Good		Partly & Badly split & Defects other than decay.		Decaying		Removed: Mainly for decay		Removed: Causes other than decay & Unknown Causes		Not inspected (under observings)	
						No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
				Lbs. per Cu. Ft.	No.												
Ties set 1927 - 11 years service																	
Borax	F	Red oak	H-S	.59[1]	100	46	46.0	45	45.0	5	5.0	2	2.0	1	1.0	1	1.0
Borax	F	Red oak	H-S	.24[1]	100	28	28.0	51	51.0	12	12.0	3	3.0	6	6.0	-	-
Zinc chloride	F	E. hemlock	S	.62[2]	112	15	13.4	52	46.4	11	9.8	1	0.9	32	28.6	1	0.9
Zinc chloride	F	Yel. birch	S	.67[2]	129	3	2.3	73	56.6	14	10.9	20	15.5	19	14.7	-	-
Zinc chloride	F	Corkbark fir	H-S	.45[2]	80	2	2.5	16	20.0	21	26.2	3	3.8	38	47.5	-	-
Ties set 1925 to 1927 - 11 to 13 years service																	
C.t.creosote, grade 1[h]	F	E. hemlock	S	15.51	284	135	47.5	105	37.0	15	5.3	2	0.7	24	8.4	3	1.1
Ties set 1928 - 10 years service																	
Arsenious acid	F	Red oak	S	.47[1]	95	54	56.8	29	30.6	4	4.2	1	1.0	7	7.4	-	-
Arsenious acid	F	Red oak	S	.27[1]	100	55	55.0	33	33.0	6	6.0	1	1.0	4	4.0	1	1.0
C.t.creosote, grade 1[h]	F	Yel. birch	S	21.43	21	15	71.4	5	23.8	-	-	-	-	1	4.8	-	-
Sodium dichromate	F	Red oak	H-S	.52[1]	96[j]	-	-	-	-	3	3.1	86	89.6	6	6.3	1	1.0
Sodium dichromate	F	Red oak	H-S	.27[1]	87[n]	-	-	-	-	-	-	82	94.3	5	5.7	-	-
Zinc-meta-arsenite	F	Red oak	S	.50[2]	97	64	66.0	23	23.7	6	6.2	1	1.0	3	3.1	-	-
Zinc-meta-arsenite	F	Red oak	S	.26[2]	112	58	51.8	38	33.9	10	8.9	1	0.9	3	2.7	2	1.8
Ties set 1929 - 9 years service																	
C.t.creosote, grade 1[h]	E	Engl.spruce	H	6.67	51	15	29.4	33	64.6	1	2.0	1	2.0	1	2.0	-	-
Natural brine	F	E. hemlock	S	16.70[p]	197	7	3.5	22	11.2	80	40.6	61	31.0	27	13.7	-	-
Nickel chromate	F	Red oak	S	.50[3]	97	6	6.2	7	7.2	59	60.8	23	23.8	-	-	-	-
Nickel chromate	F	Red oak	S	.25[3]	99	1	1.0	-	-	22	22.2	75	75.8	-	-	-	-
Zinc chloride	E	Engl.spruce	H	1.07[2]	76	3	3.9	38	50.0	13	17.1	5	6.6	16	21.1	1	1.3
Zinc chloride	T	Engl.spruce	H	.61[2]	84	6	7.1	64	76.2	6	7.1	-	-	4	4.8	4	4.8
C.t.creosote, grade 1[h]				8.36[r]													
Ties set 1927 to 1929 - 9 to 11 years service																	
Untreated	-	Corkbark fir	H-S	-	150	2	1.3	9	6.0	29	19.3	79	52.7	27	18.0	4	2.7
Ties set 1930 - 8 years service																	
C.t. creosote, grade 1[h]	F, E	Corkbark fir	H-S	10.11	40	1	2.5	23	57.5	5	12.5	-	-	11	27.5	-	-

Note: This test is being conducted in cooperation with the U. S. Forest Products Laboratory.
For a detailed description of this test see "University Avenue Test Track at Madison, Wisconsin", page 136, Proceedings of the American Wood Preservers' Association for 1935.

[a] F = full cell method
E = empty cell method
T = two movement method

[b] H = hewed ties; S = sawed ties; H-S = both hewed and sawed tiee.

[c] Rail and plate cutting, splitting, crushing, etc.

[d] 1% solution made by adding 6 gal. of concentrated Aczol solution furnished by Zinsser & Co. to each 94 gal. of water.

[e] Dry salt.

[f] Includes 2 white oak ties.

[g] Includes 4 white oak tie.

[h] A.W.P.A. specifications.

[i] Petroleum

[j] $Na_2B_4O_7.10H_2O$

[k] Based on available As_2O_3 in solution

[m] $Na_2Cr_2O_7.2H_2O$

[n] Average life 5.9 years.

[o] Based on available $ZnAs_2O_4$ in solution.

[p] Estimated absorption of brine.

[q] Based on sum of nickel sulphate & sodium cromate in solution. The available nickel chromate constitutes 53.1% of the total weight of the two salts.

[r] Creosote.

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Condition of Experimental ties in the Chicago, Milwaukee, St. Paul and Pacific Railway test track near Hartford, Wisconsin after about 27 years service

Ties set October 1911 — Ties inspected October, 1938

Preservative	Process	Tie plates	Average absorption	Ties in Test	Good		Partly or badly split but showing no decay (many ties also rail cut)		Decaying (some ties also split and rail cut)		Removed: Mainly for decay		Removed: For causes other than decay & unknown causes[b]	
					No.	%	No.	%	No.	%	No.	%	No.	%
			Lbs. per Cu. Ft.	No.										
Chestnut														
Zinc chloride[1]	Burnett[c]	Flat	12.5[d]	10	-	-	-	-	-	-	5	50.0	5	50.0
Zinc chloride[2]	Burnett[c]	Ribbed	12.5[d]	13	-	-	-	-	-	-	6	46.1	7	53.9
Spruce														
Mercuric chloride	Kyan	Flat	----[e]	13	-	-	-	-	5	38.5	7	53.8	1	7.7
Mercuric chloride	Kyan	None	----[e]	12	-	-	-	-	4	33.3	6	50.0	2	16.7
Maple														
Creosote	Full cell	None	10.7	50	5	10.0	33	66.0	12	24.0	-	-	-	-
Creosote	Full cell	Flat	12.2	49	8	16.3	36	73.5	5	10.2	-	-	-	-
Creosote	Rueping	Flat	5.0	50	7	14.0	32	64.0	10	20.0	1	2.0	-	-
Creosote	Rueping	None	4.8	50	4	8.0	34	68.0	12	24.0	-	-	-	-
20% creosote, 80% zinc chloride	Card	None	14.7[f]	50	4	8.0	18	36.0	24	48.0	3	6.0	1	2.0
20% creosote, 80% zinc chloride	Card	Flat	17.3[f]	50	-	-	26	52.0	21	42.0	2	4.0	1	2.0
Semi-refined paraffin oil	Full cell	Flat	11.1	50	-	-	31	62.0	14	28.0	2	4.0	3	6.0
Semi-refined paraffin oil	Full cell	None	14.3	49	-	-	33	67.4	13	26.5	1	2.0	2	4.1
Zinc-chloride-creosote	Two movement	Flat	16.4[g]	50	-	-	9	18.0	31	62.0	5	10.0	5	10.0
Zinc-chloride-creosote	Two movement	None	15.1[g]	50	2	4.0	1	2.0	23	46.0	21	42.0	3	6.0
Zinc chloride	Burnett	None	20.1[h]	49	-	-	-	-	1	2.0	26	53.1	22	44.9
Zinc chloride	Burnett	Flat	20.1[h]	50	-	-	-	-	22	44.0	20	40.0	8	16.0
Untreated[3]	- -	None	-	50	-	-	-	-	-	-	50	100.0	-	-
Untreated[4]	- -	Flat	-	50	-	-	-	-	-	-	50	100.0	-	-
Red oak														
Creosote	Full cell	None	11.2	52	2	3.8	44	84.7	5	9.6	-	-	1	1.9
Creosote	Full cell	Flat	10.9	50	12	24.0	35	70.0	2	4.0	-	-	1	2.0
Creosote	Rueping	Flat	5.0	50	6	12.0	24	48.0	18	36.0	1	2.0	1	2.0
Creosote	Rueping	None	5.7	50	-	-	35	70.0	12	24.0	2	4.0	1	2.0
20% creosote, 80% zinc chloride	Card	None	15.5[f]	50	-	-	10	20.0	31	62.0	2	4.0	7	14.0
20% creosote, 80% zinc chloride	Card	Flat	15.2[f]	50	1	2.0	11	22.0	38	76.0	-	-	-	-
Semi-refined paraffin oil	Full cell	Flat	8.4	50	1	2.0	3	6.0	43	86.0	2	4.0	1	2.0
Semi-refined paraffin oil	Full cell	None	6.2	49	-	-	2	4.1	31	63.2	7	14.3	9	18.4
Zinc chloride-creosote	Two movement	Flat	14.7[g]	50	1	2.0	6	12.0	33	66.0	5	10.0	5	10.0
Zinc chloride-creosote	Two movement	None	16.0[g]	50	1	2.0	3	6.0	29	58.0	11	22.0	6	12.0
Zinc chloride	Burnett[c]	Flat	12.5[d]	206	-	-	-	-	7	3.4	133	64.6	66	32.0
Zinc chloride	Burnett[c]	Ribbed	12.5[d]	53	-	-	-	-	5	9.4	29	54.8	19	35.8
Zinc chloride	Burnett	None	15.9[i]	50	-	-	-	-	20	40.0	21	42.0	9	18.0
Zinc chloride	Burnett	Flat	16.4[i]	50	-	-	-	-	34	68.0	9	18.0	7	14.0
Untreated[3]	- -	None	-	50	-	-	-	-	-	-	50	100.0	-	-
Untreated[4]	- -	Flat	-	50	-	-	-	-	-	-	50	100.0	-	-

(Continued)

Condition of Experimental ties in the Chicago, Milwaukee, St. Paul and Pacific Railway test track near Hartford, Wisconsin after about 27 years service. (Contnd)

Note: This test is being conducted in cooperation with the U. S. Forest Products Laboratory.

[a] Rail cutting, splitting, etc.
[b] Ties not available for examination after removal to determine the cause of removal.
[c] Obtained from regular stock of C.M.St.P.& P. Ry.
[d] 4% zinc chloride solution.
[e] Steeping treatment in cold mercuric chloride solution- absorption figures not available.
[f] Emulsion of 80 parts of 3% zinc chloride solution and 20 parts of creosote by volume at approximately 70°F.
[g] 3% zinc chloride solution plus creosote. Treatment consisted of bath in hot creosote for 30 minutes at atmospheric pressure followed by pressure treatment with 3% zinc chloride solution.
[h] 2-1/2% zinc chloride solution.
[i] 3% zinc chloride solution.

[1] Average life 15.6 years.
[2] Average life 13.4 years.
[3] Average life 6.4 years.
[4] Average life 7.8 years.
[5] Average life 8.7 years.
[6] Average life 9.2 years.

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Condition of Experimental ties in the Chicago, Milwaukee, St. Paul and Pacific RailWay test track near the Fair Grounds, Madison, Wisconsin.

Results of September, 1938 inspection.

Species	Preservative	Average absorption	Ties in Test	Good		Partly or badly split but showing no decay		Decaying (some ties also splitting)		Removed: Mainly for decay		Removed: For causes other than decay	
				No.	%	No.	%	No.	%	No.	%	Number	Percent
		Lbs. per Cu. Ft.	No.										
				Ties set 1916 - 22 years service									
Red oak	Zinc chloride	0.55	163	-	-	1	0.6	11	6.7	145	89.0	6	3.7
Red oak	25% creo. and 75% gas oil	10.20	75	27	36.0	33	44.0	8	10.7	3	4.0	4	5.3
Red oak	10% creo. and 90% gas oil	10.00	98	37	37.7	28	28.6	18	18.4	1	1.0	14	14.3
				Ties set 1917 - 21 years service									
Douglas fir[a]	Creosote	11.50	28	24	85.7	1	3.6	-	-	1	3.6	2	7.1
Douglas fir[b]	Untreated[c]	-	38	-	-	-	-	-	-	36	94.7	2	5.3
Douglas fir	Untreated[d]	-	47	3	6.4	-	-	4	8.5	34	72.3	6	12.8
Western larch	Untreated	-	44	-	-	-	-	-	-	43	97.7	1	2.3
White oak	Untreatsd	-	95	-	-	-	-	3	3.2	91	95.7	1	1.1
Red oak	Sodium fluoride	0.52	99	1	1.0	-	-	78	78.8	19	19.2	1	1.0
Red oak	Water gas tar	9.79	100	51	51.0	49	49.0	-	-	-	-	-	-
				Ties set 1919 - 19 years service									
Douglas fir[b]	Zinc chloride	0.52	105	3	2.8	9	8.6	27	25.7	30	28.6	36	34.3
Western larch	Zinc chloride	0.48	95	5	5.3	4	4.2	15	15.8	25	26.3	46	48.4
Red oak	50% C.T.creo. & 50% W.T.creo.	9.50	62	33	53.2	11	17.8	14	22.6	2	3.2	2	3.2
Slippery elm	50% C.T.creo. & 50% W.T.creo.	10.85	25	4	16.0	17	68.0	1	4.0	-	-	3	12.0
Butternut	50% C.T.creo. & 50% W.T.creo.	9.00	9	1	11.1	-	-	5	55.6	2	22.2	1	11.1
White oak	50% C.T.creo. & 50% W.T.creo.	7.30	1	1	100.0	-	-	-	-	-	-	-	-
Cherry	50% C.T.creo. & 50% W.T. creo.	10.50	3	-	-	2	66.7	1	33.3	-	-	-	-
Red oak	Wood tar creosote	10.08	100	7	7.0	3	3.0	46	46.0	20	20.0	24	24.0
				Ties set 1921 - 17 years service									
Red oak	Low temperature coal tar oil	10.30	100	43	43.0	38	38.0	18	18.0	-	-	1	1.0
Red oak	20% coal tar and[e] 80% low temp. coal tar oil	10.50	100	50	50.0	47	47.0	3	3.0	-	-	-	-
Red oak	Vertical retort C.T. creo.	9.60	100	66	66.0	29	29.0	5	5.0	-	-	-	-
Red oak	Pintsch gas tar	10.50	100	54	54.0	43	43.0	3	3.0	-	-	-	-
				Ties set 1927 - 11 years service									
Jack pine	Zinc chloride	0.52	381	188	49.3	22	5.8	168	44.1	3	0.8	-	-

Note: This test is being conducted in cooperation with the U.S. Forest Products Laboratory.

[a] Rail cutting, splitting, etc.
[b] Western Washington and Oregon type.
[c] Switch ties- average life 6.5 years.
[d] Average life - 10.7 years.
[e] Reported as 50% tar and 50% low temp. coal tar oil prior to 1935.

U.S.DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN
Proj. L-214

CHICAGO & NORTH WESTERN RAILWAY

Report of Twenty-Third Annual Inspection of Test Ties Installed in 1914

The results found from the 1937 inspection of test ties placed in 1914 on the Chicago & North Western Railway tracks are given in the accompanying tabulations. At each of eight locations in five states, there were placed test ties of seven varieties of wood. Each test section consisted of 100 ties of each of the seven woods, and of each of the treatments, cresosote, Burnett and Card; also, untreated.

The absorption per cubic foot of wood for the various treatments was: creosote, 7.0 lb. of creosote; Burnett, 0.50 lb. of zinc chloride; Card, 0.43 lb. of zinc chloride and 1.8 lb. of creosote.

Tests were also made for loblolly pine only with the tar treatment of 50 percent coke oven tar and 50 percent water gas tar.

The total number of ties in the test sections covered by this report is 23,172.

Average Life of Untreated Ties in Years

Variety	*Number Placed*	*Average Years Life*
Yellow Birch	800	5.2
Red Oak	799	6.5
Hard Maple	800	5.9
Loblolly Pine	799	5.0
Long Leaf Pine	792	5.9
Tamarack	801	7.1
Hemlock	798	6.7

Laona—(Saunders) Scott Lake Treated Ties

The Chicago & North Western, when constructing the line between Laona, Wis., and Saunders, Mich., in 1905, placed 74,656 zinc treated crossties between M.P. 93 plus 4,980 ft. and M.P. 120 plus 2,400 ft. These ties were hemlock and tamarack, largely hemlock, hewn and seasoned. They were treated at the railroad's Escanaba tie treating plant with zinc chloride, tannin and glue. (Wellhouse Process) The average absorption of zinc chloride was 0.433 lb. per cu. ft. of wood.

This line was laid with re-rolled 80-lb. rail, or approximately 74-lb. rail with Wolhaupter tie plates on curves only. The traffic consists of about six trains per day operated by R-1 Power. The ballast is gravel and cinders.

Careful yearly record has been kept of the removals of these ties. Only 78 percent of these ties had been removed up to Dec. 31, 1937. The estimated average life of these 74,656 ties, based on Goltra's formula, is 25.5 years.

Fort Pierre-Rapid City Treated Ties

When constructing the P.R.C. Ry. in 1906–07, the C. & N. W. used Wellhouse treated crossties entirely between Fort Pierre and Rapid City, S. D. A total of 483,840 Wisconsin and Michigan grown hemlock, ties 7-in. by 8-in. by 8 ft., hewn and seasoned were used. They were treated at the tie treating plant at Escanaba. The ballast of the P.R.C. Line is gravel; the weight of rail is 60-lb., spacing of ties is 22 in., tie plates are placed on curves.

Careful yearly records have been kept of the removals of these ties. In 1932 all but 13,984 of the ties had been removed. Estimating the additional life of these 13,984 ties it was found that the 483,840 had given an average life of 17.9 years.

Summary of 1937 Inspection of Test Tie Sections—Results of 23 Years Service

Process	Total Placed	Total Removed To Date	Percent Removed Account Decay	Percent Removed Account Other Causes	Estimated Years Average Life
Creosote	5,606	2,196	29	10	26
Burnett	5,585	4,787	76	14	16
Card	5,593	4,694	73	11	18
Tar	799	189	17	7	30
Untreated	5,589	5,589			6.1*
	23,172				

* Actual average years life.

1937 Inspection of Test Tie Sections—Results of 23 Years Service

Process	Total Placed	Total Removed To Date	Percent Removed Account Decay	Percent Removed Account Other Causes	Estimated Years Average Life
Yellow Birch Ties					
Creosote	806	52	4	2	30
Burnett	803	631	70	9	18.8
Card	793	712	79	11	16.6
Untreated	800	800			5.2*
Red Oak Ties					
Creosote	800	170	13	8	28
Burnett	783	646	70	13	17.3
Card	799	612	60	17	19.0
Untreated	799	799			6.5*
Hard Maple Ties					
Creosote	803	281	30	5	26.2
Burnett	803	646	76	5	19.2
Card	799	672	77	7	19.1
Untreated	800	800			5.9*
Loblolly Pine Ties					
Creosote	794	237	20	10	26.5
Burnett	794	754	91	4	14
Card	806	701	82	5	17.1
Untreated	799	799			5.0*
Tar	799	189	17	7	27.8
Long Leaf Pine Ties					
Creosote	800	386	35	13	25.4
Burnett	802	727	84	7	15.8
Card	793	655	75	8	17.1
Untreated	792	792			5.9*
Tamarack Ties					
Creosote	803	489	37	24	22.9
Burnett	800	658	67	15	17.8
Card	802	645	68	13	18.1
Untreated	801	801			7.1*
Hemlock Ties					
Creosote	800	581	62	11	20.1
Burnett	800	725	77	14	16.5
Card	801	697	72	15	16.9
Untreated	798	798			6.7*

* Actual average years life.

FOREST PRODUCTS LABORATORIES OF CANADA

Project 79

In 1929 100 ties of ten species, yellow birch, white birch, maple, beech, red oak, jack pine, red pine, Douglas fir, eastern hemlock and western hemlock, a total of 1,000 ties were treated at the laboratories with 0.25 lb. of zinc-meta-arsenite per cubic foot of wood.

The ties were installed in the main line of the Canadian National Railways at Gananoque Junction, Ont., in 1930.

The ties were inspected in October, 1938, and were found to be in good condition. Unless the ties deteriorate very rapidly in the next few years, the average life will apparently be considerably more than 16 years. At the present time only one or two percent of the beech, maple and birch ties show signs of early failure and it was noted that some of these ties were partially decayed when treated.

	Track Numbers
Beech	No. 126—Broomed on end
Maple	No. 215—Decayed in center
Maple	No. 268—Decayed in center
Yellow Birch	No. 283—Decayed in center
Yellow Birch	No. 348—Split

Number of ties installed in 1930 and remaining in track October, 1938.

88	Eastern hemlock	95	White birch
92	Douglas fir	97	Yellow birch
93	Western hemlock	95	Hard maple
95	Red pine	93	Beech
77	Jack pine	94	Red Oak

NORTHERN PACIFIC

Record Test Track No. 1–A

Location: Mile Post 89, near Rice, Minn., to Mile Post 103½, near Gregory, Minn., in eastward main track on St. Paul division. Ties laid in spring of 1917. Established as Record Test Track January 10, 1922.

Ties: 44,159 hewed Minnesota tamarack.

Treatment: Brainerd tie treating plant, December, 1916. Air seasoned. Bored and adzed for 90-lb. rail. Treated by Lowry process, 6¾ lb. per cu. ft. with creosote-coal tar solution, 80 percent creosote and 20 percent refined coal tar.

Analysis of Preservatives

Spec. Gravity at 38 deg. C.	1.074
Water	.000
Distillation:	Percent
210 deg.	1.1
235 deg.	10.7
270 deg.	28.6
315 deg.	15.2
355 deg.	18.7
Residue	25.6 soft paste

Track: Originally 90-lb. rail with N.P. standard angle bars and 7-in by 9-in tie plates. Average gravel ballast about six inches under the ties. In 1923 about 3½ miles of

washed gravel from Darling pit was placed on the east end of this track. In 1928 four miles (M.P. 93½ to 97½) were relaid with 100-lb. rail and 7¾-in. by 10¾-in. ties plates.

Renewals: No renewals up to 1928.

1928—	1	Tie account decay, showed signs of having been partially decayed when treated.
1929—	239	Ties account derailment.
1930—		No renewals.
1931—	3	Ties account decay.
1932—		No renewals.
1933—		No renewals.
1934—		No renewals.
1935—	214	Decay at rail base caused by mechanical wear.
1936—	1,785	Decay at rail base caused by mechanical wear.
1937—	3,002	Decay at rail base caused by mechanical wear.
1938—	3,454	Decay at rail base caused by mechanical wear.

Total—8,698 Ties renewed, 19.7 percent after 21 years.

Average life of ties removed—19.9 years.

Date of last inspection—October 12, 1938.

Hemlock Test Track

Designated by U.S. Forest Service as Project L–214

Location: Between M.P. 120 and M.P. 121+ 2,350. Westward main track. West end of Missoula yard; 400 ties east and 1400 ties west of Cemetery crossing, Missoula, Mont., Rocky Mountain division.

Ties: 1,800 (summary by species shown below). Treated at Paradise, Mont., and placed in track February, 1910. 1910 dating nail driven in each tie.

Treatment: At Paradise tie treating plant, February 1910. Air seasoned, not bored, adzed or incised. Lowry process. 6¾ lb. per cu. ft. Creosote coal-tar solution. 80 percent No. 1 creosote and 20 percent refined coal tar.

Track: Ties originally laid without tie plates. 7-in. by 9-in. tie plates applied within first two years. In 1926, track relaid with 100-lb. rail and 7¾-in. by 10¾-in. N.P. plates. Ballast is ordinary pit-run gravel and drainage is not considered good.

Summary by Species and Record of Renewal:

Annual inspections and reports made since 1917 when, on account of derailment, the first tie was removed. Positive identification of ties by species made in 1928 in co-operation with U. S. Forest Products Laboratory proved as shown below. The 49 ties replaced previously had been reported as Western hemlock.

Identification of 1910 Ties Remaining in 1928

Year	Western Hemlock	Western Larch	Douglas Fir	True Fir	Spruce	White Ponderosa Pine	Pine	Aspen	Total
1910	1072	436	166	102	18	2	3	1	1800
				Renewals					
Year									
1917	1								1
1924	1								1
1926	4								4
1928	43								43
1929	26	8	6	14	5				59
1932	49	9			3				61
1933	28	8	4	1	1				42
1934	43	18	1	6					68
1935	29	9	5	4					47
1936	42	11	3	1			1		58
1937	78	24	4	5	4				115
1938	72	24	1	6					103
Total	416	111	24	37	13	0	1	0	602
Percent Renewed	38.81	25.46	14.46	36.27	72.22	0	33.33	0	33.44
Avg. Yrs. Per Tie	24.15	25.20	23.71	23.30	22.46	0	26.00	0	24.24

Six ties removed prior to 1928 were broken by derailment; others all removed account decay hastened by damage from past derailments and mechanical wear at rail base.

33.44 percent renewals in 28 years.

Average life of ties replaced 24.24 years.

SOUTHERN PACIFIC RAILROAD

Serviceability of Ties in the Rio Grande Valley Lines

Records are being kept on a total of 375,519 ties in main line track south of Falfurrias, Tex. The ties were laid when this track was constructed, between October, 1926, and October, 1927. Most of the rails used were 75-lb., 39 ft. long, with some 90-lb. 31 ft. long. All ties were provided with plates at the time of construction. The ties are 7 in. by 8 in., 8 ft. long. Of the 375,519 ties under observation, 216,519 are treated with 7 lb. per cu. ft. of a 70 percent coal tar-creosote (residue under 20 percent) and 30 percent crude oil solution and 159,000 are treated with 5 lb. of grade 1 coal tar-creosote.

Of the ties treated with straight creosote, about 9,000 are gum and about 150,000 pine. The creosote-oil treated ties consist of about 100,000 pine, nearly 94,000 gum and over 22,000 oak. Most of the gum and oak ties were cut from the heart centers of large logs and received a poor penetration of preservative.

The climate in the region in which these ties are in service is semi-arid, with an average rainfall approximating 24 in. and an average temperature range runnning between a minimum of 30 deg. and a maximum of 100 deg. F.

Record of Tie Removals to December 1937 After About 10 to 11 Years Service

Species	Total main Line ties[1]	Renewals[2] Number	Renewals[2] Percent
Pine	250,119	9,138	3.7[3]
Gum	102,948	41,430	40.2
Oak	22,452	13,934	62.1

[1] About 100,119 pine, about 93,948 gum and all the oak ties were treated with 7 lb. of a 70–30 creosote-crude oil solution. About 150,000 pine and 9000 gum ties were treated with 5 lb. of Grade 1 creosote.

[2] Renewals not separated by treatment.

[3] Reported that most of the pine ties renewed were treated with 5 lb. of Grade 1 creosote.

Appendix C

(3) PILES USED FOR MARINE CONSTRUCTION

Wm. G. Atwood, Chairman, Subcommittee; C. S. Burt, Wm. F. Clapp, H. R. Condon, G. R. Hopkins, H. E. Horrocks, M. F. Jaeger, Dr. A. L. Kammerer, A. M. Knowles, F. B. Robins.

The committee submits its report on the condition of the long-time test pieces under its observation, together with such other pertinent information as it has secured during the year.

Turpentine Wood

The test specimens at Panama, installed in 1929, show some attack by limnoria and also have a few teredo in the sapwood.

The pieces at Castle Pinckney in Charleston, S. C., harbor have been heavily attacked by teredo.

Fifty turpentine wood piles were driven in the Oakland pier of the Southern Pacific Company in 1927–28. Twenty of these piles were inspected in November, 1937. One was found to have a rather heavy limnoria attack and all but one of the others had an insignificant attack. There were no teredo.

Practically no other timber is used for piers in Australian harbors. There are some piers in "Darling Harbor", Sydney, N. S. W., with turpentine wood piles nearly 50 years old. Unprotected fir lasts about six months in this location.

Panama Canal

Through the courtesy of Brig. Gen. C. S. Ridley, governor of the Panama Canal Zone, the committee is able to submit the following report from this area:

"In connection with the annual inspection of timbers undergoing test for resistance against marine borers at Balboa, Canal Zone, please be advised that the 1938 inspection was performed on August 9, 1938, and under date of August 24, 1938, Mr. James Zetek submitted the following report:"

> Since last year we eliminated all timbers but one, of those which were not showing marked teredo resistance, we have left only those which have been very resistant, hence this year's report is very brief, in fact there is little to report. The only untreated timber that had to be closed at this time was Chachajo (1644–28) and last year I was certain that it would become a failure at our next examination. It has no teredo resistance whatever. All of the other untreated were practically the same as in 1937.
>
> I was particularly pleased to see the excellent condition of the two Chemonite treated timbers, but it is too early to say much. The pin holes noted are probably the beginning of a teredo invasion.
>
> Only *Limnoria lignorum* (Rathke) was noted. No evidence was seen of either *Sphaeroma* or *Chelura*. The two pholads were *Hiata infelix* Zetek and McLean and *Martesia striata* L., and the only teredo noted was *Neobankia zeteki* (Bartsch).
>
> No photographs were made this year.

A—Untreated Timbers

1609–2 Anoura, *Conepia sp.*, Dutch Guiana, submerged September 12, 1923. There was practically no change. The cut surface (1937) shows no gribble work and very little marine growth. The teredo work is insignificant.

1612–3 Basra Locus (Angelique), *Dicorynia paraensis* (Bentham), Dutch Guiana, submerged September 13, 1923. Very little change, if any, from last year. The 1937 cut surface is very clean, no marine growth or gribble. Teredo work insignificant.

1608–4 Foengo, *Parinarium campestre* (Aubl.), Dutch Guiana, submerged September 13, 1923. No change since last year. The 1937 cut surface is very clean. Teredo work insignificant.

1610–5 Sponse Hoedoe, *Licania macrophylla* (Benth.), Dutch Guiana, submerged September 13, 1923. No marked change since last year excepting an increase of gribble damage. The 1937 cut surface is very clean. *Hiata* and *Martesia* do most of the damage. Teredo only close to the surface and small in size.

1613–7 Manbarklak, *Eschwilera longipes,* (Miers), Dutch Guiana, submerged September 13, 1923. No change since last year. The 1937 cut surface is very clean of growth.

1606–9 Malabayabas, *Tristabia decorticata* (merr.), Philippine Islands, submerged September 13, 1923. No change since last year. The 1937 cut surface is very clean of marine growth.

1615–11 Kajol Lara, *Metrosideros* sp., Celebes, submerged October 16, 1925. The general picture does not differ from last year. Gribble work is very light, teredo few in number and small, close to surfaces. The two pholads do more actual damage than does the teredo.

1616–12 Kajol Malas, *Parastemon urophyllum,* Sumatra, submerged October 26, 1926. No change since last year. The gribble work is more than in Kajol Lara.

1637–13 Kolaka, Celebes, submerged April 15, 1932. There was considerable silt present. Gribble work appeared to have increased since last year. Otherwise there was no change noted since 1937.

1617–14 Alcornoque, Dimorphandra mora, (B & H), Panama, all heartwood, submerged November 27, 1927. No marked change since 1937 except perhaps a slight increase in gribble work on one face.

1625–22 Brush-box, New South Wales, submerged November 22, 1927. Considerable silt otherwise no change since 1937.

1621–25 Turpentine wood, *Syncarpia laurifolia,* New South Wales, submerged April 19, 1929. Very much as last year.

1621–27 Turpentine wood, *Syncarpia laurifolia,* New South Wales, submerged April 19, 1929. No marked change since last year.

1644–28 Chachajo, size 2 in. by 2 in. by 12¾ in., Colombia, submerged February 10, 1937. This piece of wood was *thoroughly* riddled by teredo *(Neoteredo zeteki)* some over ½ in. in diameter, and a rather large number of both *Martesia* and *Hiata.* Closed.

B—Treated Timbers

1630–30 Creosoted Amarillo, *Chlorophora tinctorea,* Panama, treated with AREA No. 1 coal tar creosote, one end scarfed *after* treatment, submerged September 20, 1930. Oysters were extremely plentiful, also some coral. Considerable silt. I was unable to note any marked change since last year, but since we cut off, in 1937, 17 in. we thereby exposed to teredo parts of the timber that had little or no creosote penetration so that we should expect teredo to work through the center of the timber.

1721–31 Chemonite Treatment, Southern yellow pine, two sticks 6 in. diameter by 7 ft. long, submerged March 12, 1937. These two posts are numbers 2447 and 2468. Marine growth was practically nil. No gribble work was noted, not even on the end surfaces. I saw no signs of *Hiata* or *Martesia* and no indications of teredo, in fact the two timbers are very sound. A few tiny pin holes were seen and these may be teredo, but I did not want to cut into the wood at this time. Having two timbers with practically the same amount of absorption, we will be able to keep one intact and cut into the other as we may find necessary. The pin holes are more in No. 2447.

Chemical Warfare Service Specimens

Series No. 1

No. 1—1 percent solution of ammoniacal copper carbonate.

Pieces with this treatment remain under test at Castle Pinckney, Charleston, S. C., at San Juan, P. R., and in San Francisco bay. All others have been destroyed. The pieces at Castle Pinckney are nearly destroyed, but those at San Juan and in San Francisco bay show little change in the last year though all of them have been attacked.

No. 2—1 percent diphenylamine in creosote.

One specimen, remains at Castle Pinckney, one at San Juan and two in San Francisco bay.

The piece at Castle Pinckney is very heavily attacked by limnoria and the others show a light attack.

No. 3—0.75 percent diphenylamine chlorarsene and 0.5 percent phenyldichlorarsene. in fuel oil.

The two specimens remaining at Castle Pinckney are practically destroyed, the one at Oakland Pier is heavily attacked by limnoria and the one at Peralta St. Pier is practically destroyed by limnoria, teredo and bankia.

Series No. 2

This series of test pieces was treated at Edgewood Arsenal in 1931. The poisons, which were used in varying proportions, were methyl arsenious oxide, diphenylamine-chlorarsene and dinitrophenol. There were three sets of pieces for which creosote was used as a carrier for the poisons and three in which fuel oil was used. One series was treated with AREA No. 1 creosote as a control series. The penetration in the ends of the pieces was very poor and this has lessened the value of the tests.

Two sets of test pieces were submerged at each of the following places: Fort Tilden, N. Y. and Castle Pinckney, in the harbor of Charleston, S. C. under the supervision of the Corps of Engineers, U. S. A.; San Juan, P. R. supervised by the Bureau of Lighthouses; Miraflores, C. Z., by the Governor of the Canal Zone; Naval Air Station, Pensacola, Fla., Puget Sound Navy Yard, Bremerton, Wash., Pearl Harbor Navy Yard, Pearl Harbor, T. H., and Cavite Naval Station, by the Bureau of Yards and Docks, U. S. N.; and in San Francisco Bay by the Southern Pacific Lines.

The attack on the test pieces at Cavite was principally by pholads and its was very heavy. Treatment gives no protection against pholads, so this series of tests was discontinued.

The creosoted pieces at Fort Tilden are under severe attack at the ends of the pieces by limnoria and teredo. They are all appreciably damagd except the pair with dinitophenol added to the creosote. On the contrary, the pieces with this poison added to fuel oil were the most severely damaged of the fuel oil series. Untreated controls were practically destroyed.

All fuel oil-treated pieces at Castle Pinckney have been destroyed. Of the creosoted pieces, the sets treated with dinitrophenol and diphenylamine chlorarsene are the least damaged and those with straight creosote the most.

There has been little change in the condition of the creosoted pieces at San Juan in the past year. All pieces treated with fuel oil have been destroyed except the one containing dinitrophenol and that has been heavily attacked.

The specimens at Pensacola, treated with creosote, all show a light attack by limnoria on the sides but the attack in the ends is heavy and some teredo have gained entrance there. All pieces treated with fuel oil have been destroyed except one with diphenylamine chlorarsene which is 98 percent gone.

In San Francisco bay the specimens with creosote and creosote plus poisons show some limnoria attack and some of them are being seriously damaged on the ends. The fuel oil treated pieces show a heavy limnoria attack except the ones treated with dinitrophenol which have a light limnoria attack. The untreated control at Oakland Pier showed a moderate limnoria attack with a few teredo, while at Peralta street the limnoria attack was heavy and the teredo attack very light.

At the Puget Sound Navy Yard only one piece, and that treated with dinitrophenol in creosote, remains. The report on this piece says: "Several Bankia burrows in the center of the piece, 5/8 in. in diameter, entering through the end. No entrance holes on the sides. As has been the case with some of the other specimens, the depth of impregnation on the ends was only 1/4 in., while the sides showed about 1½ in."

The creosoted pieces at the coaling wharf at the Pearl Harbor Navy Yard are badly damaged, those with diphenylamine chlorarsene and dinitrophenol are the least injured. The specimens treated with fuel oil are from 75 percent to 90 percent destroyed, while the untreated control was entirely destroyed. The set of specimens under Pier 1 were in about the same condition, those with the same two poisons being the least damaged. Of the fuel oil treated pieces the one with dihpenylamine chlorarsene was entirely destroyed and the other two about 50 percent destroyed. The attack on all the test pieces by pholads was fairly heavy.

Barrett Manufacturing Co. Material

Thirty test pieces were treated with creosotes of varying composition and two methods of manufacture. They were immersed in San Francisco bay in 1923. Their condition has not changed during the year except for the beginning of a light limnoria attack on the pieces treated with coke oven and vertical retort creosote with the solids

removed and one treated with vertical retort creosote with residue above 360 deg. removed. The untreated controls showed a moderate limnoria attack.

No report is submitted this year on the old piles.

Metal Sheathed Piles

Copper sheets and Monel sheets were used to sheathe piles at Cat Island Light, in the Gulf of Mexico and at Key West, Fla. This work was done in 1923. As has been previously reported, the sheets were found to contain many pin holes at Cat Island Light and they were further protected by concrete sleeves. The piles at Key West were examined in June, 1938 and were found to be in excellent condition, though the Monel sheets show some signs of pitting. The piles above water level are decayed and have been attacked by termites.

New York City

An organization for the study of the marine borer problem has been formed in New York Harbor. Mr. Walter P. Hedden, president of Marine Terminal Operators Atlantic Ports, is at the head of the organization. So far, 34 test boards have been placed and arrangements have been made for water analyses at many of the test locations.

New England Report

The investigation which has been conducted for the last four years under the direction of the New England Marine Piling Committee is still being carried on. About 20 additional test boards have been put in operation since the last report. These are located in harbors where boards had not been previously placed. A total of about 200 boards is now being operated. A number of boards have been discontinued because it had appeared clear that no attack was likely to occur under present conditions.

Test board and other studies conducted by the State of Connecticut under the direction of Gen. S. H. Wadhams has been continued with the addition of several new locations.

The annual report of the New England committee has not yet been completed but the general results were:

During the year 1938 there has been a very marked decrease in *Teredo navalis* activity and resulting destruction. In a number of harbors where sets of teredo occurred in 1936 and 1937, no teredo appeared in 1938. In some other harbors, while a set occurred, it was very light compared with the two previous years.

No teredo appeared at any of the test board stations in Bostor harbor where attack was registered in 1937. On the other hand, there has been a very marked increase in the limnoria census.

A large number of various species of timber reported to be more or less resistant to marine borer attack have been submerged at the tropical testing stations. Approximately 1,000 timbers treated with various proprietary and other preservatives have added to those already exposed at the testing stations in Newport, R. I., and in the tropics.

The recent hurricane resulted in the loss of 15 test boards in Connecticut and Rhode Island. These have been replaced.

The losses at the Newport testing station due to the hurricane can not yet be estimated. It is known that many timbers which have been exposed since 1934 have been lost. This is particularly unfortunate in the case of more than 100 timbers impregnated with various combinations of creosote and coal tar. The results of several years exposure will be lost unless these timbers can be recovered.

"Sea Action Committee", England

The 16th and 17th Interim Reports (1936 and 1937) have been received. These reports give information regarding the results of tests of treatments with specification creosote, fuel oil and these two used as carriers for poisons very similar to those used in the Chemical Warfare Service specimens reported by this committee. The results of these tests carried on in British harbors in many parts of the world are very much like those reported by this committee. There is little evidence to show that the poisons appreciably increase the resistance to teredo attack and some of the evidence indicates that some of the poisons attract limnoria.

Because some of the older engineers strongly contended that the old "London Dead Oil of Coal Tar", containing a higher percentage of napthalene than is found in the

creosote considered standard at present was more effective, the Sea-Action committee prepared test pieces treated with standard creosote, creosote with napthalene added and napthalene with poisons added. One series of these specimens was exposed at Mauritius for six years and has recently been removed and inspected. All show a heavy attack by limnoria. The specimens treated with creosote and by a double treatment with creosote followed by napthalene were the most resistant. A similar series was exposed at Takoradi, Gold Coast, and the same results were obtained under very heavy limnoria attack.

The corrosion tests of metals have been closed at Auckland, N. Z., Colombo, Ceylon, Halifax, N. S., and Plymouth, England after 15 years exposure.* The results of these tests as stated in the 17th Interim Report are as shown in the tables.

One set of specimens at each station was exposed above high tide, in the tidal range and below low tide. All figures are loss in weight of each piece in grams.

* Reports for the five and ten year inspections will be found in "Transactions", Vol. 35, page 747, Vol. 36, page 510, Vol. 31, page 700 and Vol. 27, page 994.

Kind of Metal	*Condition*	*Halifax*	*Aucklank*	*Plymouth*	*Colombo*
Aerial Exposure					
Low Moor wrought iron	Cleaned	535	797	1,293	2,676
Swedish charcoal iron	Cleaned	432	1,629	1,776	3,458
Ingot iron	Cleaned	516	1,286	1,935	3,309
Mild steel, low Mn, high S & P	With scale	448	1,285	2,181	2,848
Mild steel, 0.7% Mn	With scale	355	857	1,932	3,020
Mild steel, 0.7% Mn	Cleaned	356	740	606	3,295
Medium carbon steel, low S & P	With scale	335	693	1,897	3,057
Medium carbon steel, low S & P	Cleaned	288	472	427	3,773
0.40% Carbon steel	With scale	307	715	1,658	2,845
Mild steel, 0.635% Cu	With scale	217	300	1,064	3,154
Mild Steel, 2.185% Cu	With scale	163	282	598	2,941
13.57% Cr. steel	With scale	30	31	50	196
3.75% Ni. steel	With scale	94	135	156	2,800
36.55% Ni. steel	With scale	16	14	43	46
Hot-blast cast iron	As cast	77	414	76	830
Cold-blast cast iron	As cast	47	410	37	1,234
Alternate Wet and Dry					
Low Moor wrought iron	Cleaned	721	216	1,048	1,464
Swedish charcoal iron	Cleaned	833	263	1,258	1,735
Ingot iron	Cleaned	811	347	1,567	1,461
Mild steel, low Mn, high S & P	With scale	1,403	190	898	1,409
Mild steel, 0.7% Mn	With scale	839	178	776	1,883
Mild steel, 0.7% Mn	Cleaned	816	298	1,409	2,032
Medium carbon steel, low S & P	With scale	605	181	698	2,614
Medium carbon steel, low S & P	Cleaned	977	274	1,232	2,347
0.40% Carbon steel	With scale	678	160	686	1,913
Mild steel, 0.635% Cu	With scale	716	134	706	1,498
Mild steel, 2.185% Cu	With scale	547	147	762	2,167
13.57% Cr. steel	With scale	78	110	312	842
3.75% Ni. steel	With scale	270	123	560	1,725
36.55% Ni. steel	With scale	119	48	181	318
Hot-blast cast iron	As cast	56	110	*	*
Cold-blast cast iron	As cast	81	73	*	*
Complete Immersion					
Low Moor wrought iron	Cleaned	1,374	649	614	955
Swedish charcoal iron	Cleaned	1,684	744	713	924
Ingot iron	Cleaned	1,720	606	972	858
Mild steel, low Mn., high S & P	With scale	1,239	945	696	946
Mild steel, 0.7% Mn.	With scale	1,223	1,084	835	1,112
Mild steel, 0.7% Mn.	Cleaned	1,215	975	778	1,207
Medium carbon steel, low S & P	With scale	1,350	1,108	671	1,343
Medium carbon steel, low S & P	Cleaned	1,404	1,205	842	1,329
0.40% Carbon steel	With scale	1,288	885	668	1,324
Mild steel, 0.635% Cu.	With scale	1,240	523	772	1,096
Mild steel, 2.185% Cu.	With scale	1,388	937	758	1,061
13.57% Cr. steel	With scale	860	465	704	379
3.75% Ni. steel	With scale	1,153	606	528	1,007
36.55% Ni. steel	With scale	719	276	435	422
Hot and cold-blast cast iron		*	*	*	*

* Not seriously corroded but graphitized, some specimens heavily.

Sir Robert Hadfield reports the results of tests of "Austentic Manganese Steel" which he finds does corrode in sea water. Shun-Ichi Satoh had reported in the Journal of Physical and Chemical Research of Japan that it did not corrode.

Reports are made of the tests of reinforced concrete, exposed in England and on the Gold Coast. The specimens were made with commercial cements, commercial cements with trass, commercial cements with artificial puzzolanas and with high alumina cements. Trass appears to be a valuable addition but artificial puzzolanas are of less value. Alumina cements do not appear to be durable when used in lean mixtures but are excellent when used in normal or rich mixtures.

Australian Investigations

In its 1933 report this committee mentioned the studies being made in Port Jackson (the body of water on which Sydney N. S. W. is located) and abstracted the current Report. See "Proceedings" Vol. 34, page 450.

During the winter of 1937–38 the chairman of this subcommittee had the privilege of seeing this work and discussing the results with Messers A. J. Debenham, engineer-in-chief, and R. A. Johnson, Research Engineer of the Maratime Services Board of New South Wales, and also Messers F. A. McNeill and Tom Iredale, zo-ologists of the Australian Museum at Sydney.

In addition to the studies being made at Port Jackson a similar investigation was started in 1931 and is still being carried on in Moreton bay and the Brisbane river, the harbor of Brisbane, Queensland. This work is under the direction of the minister of lands and Mr. C. J. J. Watson, senior assistant of the Investigations section of the Queensland Forest Service with the collaboration of the research staff of the Maratime Services Board and the Australian Museum at Sydney. A supplementary report for Port Jackson and a first report for Moreton bay and the Brisbane river were issued in 1936.

The general method of work is similar to that of the Committee on Marine Piling of the National Research Council to whose records and tests this subcommittee succeeded in 1924.

Port Jackson is a rather long and narrow bay with a very irregular shore line. The length of the shore line of the bay is 188 miles. Sydney is located toward the western end and the industrial development is near the city.

Because of the deeply indented shore line and the differing developments in the various bays as well as the inflow of fresh water from the Parrammatta river, the conditions influencing the growth of marine borers varies greatly in different parts of the harbor. The test stations are so distributed as to get an accurate record of the various organisms and enough water analyses are made to keep a check on conditions.

The species of borers identified are: three species of *Sphaeroma,* one of *Exosphaeroma,* one of *Limnoria* and one of *Chelura* among the crustaceans and four species of *Bankia,* four species of *Teredo,* one species of *Neoteredo,* and one of *Nausitoria.*

The wharves are concentrated in four bays and are built on turpentine wood piles. These statements apply to the main wharves for heavy traffic. There are many small wharves scattered around the shore line. Some of these main wharves have piles under them which have been in service for nearly fifty years. An untreated fir pile will last about six months in the vicinity of the oldest of these wharves.

These turpentine wood piles are attacked by the crustacean borers to some extent but the zone of attack is in the tidal range (about six feet). In order to protect against these crustaceans, the research engineer has invented a floating sleeve which is filled with creosote lighter than sea water. This sleeve is clamped around the pile, the creosote poured in and the sleeve left to float up and down the pile for 24 hours and then moved to another pile. This time is sufficient to kill the borers and enough creosote is left so that an attack is unlikely for several years. It is a very simple and inexpensive method of protecting against an attack that is as limited in area as it is in Sydney.

The men regularly employed handling the sleeves also inspect the timber in the wharves as they go along. They are furnished with a small air pressure tank, hose and nozzles of various shapes. When they find incipient decay or cracks where fungi are likely to land they fill the opening with creosote under pressure. The native timber does not decay readily and is really comparable to our treated timber. Engineer-in-Chief Debenham considers this method of deterring the attacks of fungi a very economical process, and it is probable that it could be used to great advantage in this country, especially in treated timber wharves.

The Port of Brisbane is 510 miles north of Port Jackson but in spite of the fact that it is more tropical there are fewer species of borers. The crustacean borers are the same as in Port Jackson but *Limnoria* and *Chelura* are rare. Only seven species of teredine borers have been identified but two of them, not infrequently, reach a diameter of one inch and a length of over six feet. The genus *Nausitoria* is represented by a species in each harbor. It lives in fresh or slightly brackish water and is the only genus known that attacks turpentine wood freely.

There are no pressure treating plants in Australia or New Zealand so when their reports refer to "creosoted timber" they mean either painted or open-tank treated wood.

As the result of their studies and experience the Australian scientists and engineers are sure that the different species of borers attack timber selectively, and that protective measures that are effective where one species is present may not be if another species is present.

Selective Attack

Students of the marine borer problem have long realized that timbers and treatments that resisted attack in one location did not do so in other locations. This has been a disturbing matter in the minds of designers of structures because the cause of the differing effectiveness of protective measures was unknown.

From rather incomplete evidence it appears probable that protective measures which inhibit attack by one or more species of borers does not effect other species to the same extent.

This has been proved to the satisfaction of the Australian scientists and engineers. Turpentine wood is the almost universal timber for piles in salt water. It is attacked to a limited extent by some of the crustaceans but is immune to the attack of any of the teredine borers except those of the genus *Nausitoria*. While this genus does not attack turpentine wood as freely as it does some of the commoner timbers it does destroy turpentine wood piles in a comparatively short time.

A letter which throws some light on this subject has come into the hands of the committee from Mr. B. R. Wood, conservator of forests of British Guiana. It is quoted below:

> With reference to your No. 42/28 of April 3, 1937, on the subject of Teredo attack on Tropical Timbers, I have not yet seen the papers in question. The extract of the report sent however speaks of a serious extension of borer attacks in New England waters, and makes a comparison with tropical timbers exposed in the Panama Canal Zone. Such comparisons are most unsafe, not only do different woods behave differently in different situations but woods in temperate waters are exposed to the attack of the *Teredo navalis,* of a different sub-genus of marine borer in addition. The comparison is made still more unsafe when results obtained in the Panama canal are used to compare with attacks in open salt water, as the water of the Panama canal, being kept replenished from the freshwater Lake Miraflores is brackish and consequently timbers there are exposed to the attacks of *Neobankia zeteki* and *Neoteredo bartschii,* the corresponding tropical teredo in this colony and Suriname is the *Neoteredo reyenii* the first of these to be discovered, and it affords an interesting example. It is a matter of common knowledge that while the teredo attack on greenheart in Georgetown and on the coast is slight, there is a belt a little way up each river where attacks are heavy, and this is the situation where the fresh water meeting the salt produces the conditions favorable to the *Neoteredo reyneii.* This was discovered first in the Saramacca canal in Suriname where it was found that greenheart failed whilst manbarklak *(Lecythis ollaria),* which is the black kakaralli of this colony, stood well. This was at once used as an argument for replacing greenheart with the Dutch colonial wood in Holland, where the water is salt and temperate, not brackish and tropical. Test piles of both timbers were driven in Flushing and the Manbarklak failed, while the greenheart still stands. Even where conditions are more nearly comparable divergent results are sometimes obtained. For instance, greenheart does not stand well in Dover, although not attacked by teredo the sholas seems to have a preference for it, whereas in the Portsmouth, Southhampton area, greenheart is exceedingly lasting when other woods are not. The steps down which Nelson walked to embark on the Victory before Trafalgar are made of greenheart and are still sound. In Trinidad, angelique, said to be resistant, have been used to replace greenheart, but have been given up

as the result of experience. The wharf at the Pitch lake was originally made of greenheart, and when it was to be rebuilt all piles showing any signs of failure were drawn and sawn into decking being replaced by creosoted pitch pine. Recently the wharf required extensive repairs when it was found that the pitch pine piles were almost completely perished and that the wharf was being supported by the old remaining greenheart piles. The wharf has now been rebuilt with greenheart.

The Forest Department has always warned engineers not to use greenheart in brackish tropical waters for the reason that it is likely to fail * * *.

The writer goes on to discuss the New England attack with special reference to the removal of sewage from the harbors, to predict that the same thing will happen in New York harbor when it is purified and gives an example of a similar occurrence in Scotland.

The theory of selective attack seems to be probably true. If it is, data as to the resistance of a given treatment or a certain timber will have to be interpreted with a knowledge of what species of borers did the damage or were present and did not attack. This will rquire the close collaboration of engineers and biologists and will require the services of biologists much more frequently than is usual at present. Information as to failures of timber or treatments should be restudied and the attacking organism identified if possible.

Summary

No conclusions are yet possible as to the relative effectiveness of the various creosotes in the San Francisco tests or of the effect of the poisons added to creosote.

The theory of selective attack by different species on various treatments and different timbers opens a wide field for study and raises a serious question as to how far it is safe to go in using such records as we have of the resistance to attack of treatments or timbers in locations other than those where the records were made.

This report is offered as information with the recommendation that the subject be continued.

Appendix D

(4) EFFECT OF PRESERVATIVE TREATMENT BY THE USE OF CREOSOTE-PETROLEUM, AND ZINC CHLORIDE AND PETROLEUM

R. S. Belcher, Chairman, Subcommittee; S. J. Buckman, G. B. Campbell, E. A. Craft, H. R. Duncan, E. B. Fulks, L. H. Harper, R. S. Hubley, R. P. Hughes, M. F. Jaeger, A. J. Loom, F. D. Mattos, O. C. Steinmayer, G. C. Stephenson, T. H. Strate, W. A. Summerhays, H. von Schrenk.

During the past 15 years, the committee has had this subject under consideration. Its first report was made to the Association in 1924[1]. In the 1924 report, the subject was divided as follows and handled by two Subcommittees:

(a) Creosote with other oils.

(b) Report on creosote-petroleum mixture for treatment of ties.

The 1924 report includes a history of the use of creosote-petroleum mixtures in this country and in Europe, and the results obtained up to that time. Previous to making the report, the committees made an exhaustive inquiry during the previous 1½ years and endeavored to obtain the latest information from foreign countries as well as from this country. The committee made three inspection trips investigating creosote-petroleum mixture ties at various points on the Santa Fe, and reported as to the length of service given by the ties inspected.

[1] Vol. 25, Pages 862 to 897.

In 1925[2], your committee reported on the two subjects:

(a) Treatment with a mixture of creosote and petroleum.
(b) Treatment with a mixture of zinc chloride and petroleum.

During the year previous to the making this report, the committee again made an inspection of creosote-petroleum mixture ties in the Cleveland test section of the Santa Fe, and the service given by these ties up to the date of the report was tabulated and included in the report.

The report included a description of a process developed at the Mellon Institute of Industrial Research, Pittsburgh, Pa., by means of which zinc chloride and petroleum were injected into the timber in the form of an emulsion composed of zinc chloride 15 percent to 40 percent strength, and a mixture of heavy asphaltic-base petroleum thinned to desired viscosity by means of gas oil or petroleum distillate. Several thousand ties were treated by this method and subsequent reports made covering service in track. This year's report gives the results to date from these ties as well as the service life of zinc-petroleum ties treated by the two-movement process.

A short progress report was made to the association in 1926[3].

The report to the association in 1928[4] is chiefly devoted to a detailed tabulation of performance of creosote-petroleum and zinc-petroleum ties in the Cleveland (Texas) test section of the Santa Fe. In this report, a comparison is made showing the superiority of the zinc chloride-petroleum treatment, compared with straight zinc chloride treatment of ties under similar conditions.

The 1930[5] report consists of a detailed report of an inspection by the committee of creosote-petroleum mixture treated ties on the Slaton and Pecos divisions of the Santa Fe, and the performance of these ties is compared with ties treated with 5 lb. of straight creosote, and with straight zinc chloride treated ties. A detailed report is given of inspection of ties in tie test on the Arizona division of the Santa Fe near Kingman, in addition to the assembling of data covering the performance of creosote-petroleum and zinc-petroleum ties in track.

This year your committee is reporting the performance to date of approximately one million ties in test tracks of the Northern Pacific, the Reading, and the Atchison, Topeka and Santa Fe. Of these, approximately 222,000 are creosote-petroleum mixture ties, 15,000 are ties treated with zinc chloride-petroleum, 16,000 are ties treated with zinc chloride, creosote and petroleum, and for comparison, the committee presents results from 790,000 ties treated with straight creosote, most of these treated with 5 lb. to the cubic foot, but a considerable portion treated with 7 lb. straight creosote to the cubic foot. The results are given in detail in the tabulations.

These tabulations show not only the actual average life in track to date, but also the expected average life reflected by the Forest Products Laboratory curve, for all groups in which the number of ties renewed lies between 10 percent and 90 percent. Beyond these limits the use of the curve is not recommnded by the Forest Products Laboratory.

In the tabulations, the ties have been separated as to kinds of wood, as to variations in the percentage of creosote in the mixture, and the net retention per cubic foot of the preservative. Many test ties of these treatments have not been included because it is the opinion of the committee that space should not be given for the reporting of ties

[2] Vol. 26, Pages 102 to 111.
[3] Vol. 27, pages 1000 and 1001.
[4] Vol. 29, pages 726 to 747.
[5] Vol. 31, pages 703 to 725.

Tabulation Showing Actual Performance to January 1, 1938, in Track, and Estimated Total Life Based on Tie-Life Curve of the Forest Products Laboratory at Madison, Wisconsin, of Ties in Test Tracks of the Santa Fe Railway, Treated With Creosote-Petroleum Mixture; Zinc Chloride, Creosote and Petroleum; and Zinc Chloride and Petroleum; and for Comparison, Ties Treated with Straight Creosote.

Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Sawn Western Yellow Pine Ties. Treatment, 10 to 12 Lbs. per Cu.Ft. 30/70 Creosote-Petroleum Mixture.				
1910	2,266	572	25.24	23.86	35.53
1911	2,259	909	40.24	20.54	30.59
1912	145	95	65.52	17.21	24.04
Total	4,670	1,576	33.75		
	Hewn and Sawn Western Yellow Pine Ties. Treatment, 7 Lbs. Per Cu.Ft. 50/50 Creosote-Petroleum Mixture.				
1912	119	41	34.45	21.51	30.86
1913	9,396	843	8.97	22.90	*
1914	712	123	17.28	21.21	32.86
1915	734	245	33.38	20.15	27.16
1922	1,599	49	3.06	14.85	*
1923	2,119	17	0.80	13.97	*
1924	1,155	27	2.34	12.88	*
1925	1,462	26	1.78	11.87	*
Total	17,296	1,371	7.93		
	Hewn and Sawn Southern Yellow Pine Ties. Treatment, 7 Lbs. Per Cu.Ft. 50/50 Creosote-Petroleum Mixture.				
1922	601	25	4.16	14.86	*
1923	2,260	72	3.19	13.95	*
Total	2,861	97	3.39		
	Hewn and Sawn Red Oak Ties. Treatment, 7 Lbs. Per Cu.Ft. 50/50 Creosote-Petroleum Mixture.				
1922	1,999	134	6.70	14.92	*
1923	801	14	1.75	13.93	*
Total	2,800	148	5.29		

Based on Forest Products Laboratory Curve.
* Percent Renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn White Oak Ties. Treatment 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1922	400	20	5.00	14.60	*
1923	400	13	3.25	13.90	*
Total	800	33	4.13		
	Hewn and Sawn Gum Ties. Treatment, 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1922	2,001	15	0.75	14.99	*
1923	148	3	2.03	13.90	*
Total	2,149	18	0.84		
	Hewn and Sawn Red Gum Ties. Treatment, 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1923	777	5	0.64	13.98	*
	Hewn and Sawn Black Gum Ties. Treatment, 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1923	544	4	0.74	13.98	*
	Sawn Pacific Coast Douglas Fir Ties. Treatment, 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1921	500	21	4.20	15.96	*
1922	5,265	561	10.66	14.51	23.44
1923	6,855	752	10.97	13.50	21.88
1924	2,277	68	2.99	12.92	*
1925	209	11	5.26	11.83	*
1926	266	1	0.38	11.00	*
Total	15,372	1,414	9.20		
	Hewn and Sawn Rocky Mountain Fir Ties. Treatment, 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1923	201	0	0.00	14.00	*
1924	68	0	0.00	13.00	*
Total	269	0	0.00		

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

Year Inserted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn White Fir Ties. Treatment, 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1922	200	4	2.00	14.98	*
1923	198	27	13.64	13.40	20.90
Total	398	31	7.79		
	Hewn and Sawn Magnolia Ties. Treatment, 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1923	200	1	0.50	13.98	*
1925	99	0	0.00	12.00	*
1926	105	0	0.00	11.00	*
Total	404	1	0.25		
	Hewn and Sawn Cottonwood Ties. Treatment 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1923	150	0	0.00	14.00	*
	Sawn Beech Ties. Treatment, 7 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1923	200	1	0.50	13.98	*
	Hewn and Sawn Southern Yellow Pine Ties. Treatment 7 Lbs. Per Cu. Ft. 70/30 Creosote-Petroleum Mixture.				
1923	54,904	882	1.61	13.98	*
1924	4,870	353	7.25	12.76	*
1925	4,272	185	4.33	11.93	*
1926	5,615	64	1.14	10.98	*
Total	69,661	1,484	2.13		
	Hewn and Sawn Western Yellow Pine Ties. Treatment, 7 Lbs. Per Cu. Ft. 70/30 Creosote-Petroleum Mixture.				
1923	737	108	14.65	13.67	20.59
	Hewn and Sawn Oak Ties. Treatment, 7 Lbs. Per Cu. Ft. 70/30 Creosote-Petroleum Mixture.				
1923	1,042	143	13.72	13.86	20.90

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

Year Inserted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn Red Oak Ties. Treatment, 7 Lbs. Per Cu. Ft. 70/30 Creosote-Petroleum Mixture.				
1923	764	13	1.70	13.97	*
	Hewn and Sawn White Oak Ties. Treatment, 7 Lbs. Per Cu.Ft. 70/30 Creosote-Petroleum Mixture.				
1923	399	6	1.50	13.94	*
	Hewn and Sawn Gum Ties. Treatment, 7 Lbs. Per Cu. Ft. 70/30 Creosote-Petroleum Mixture.				
1923	4,479	264	5.89	13.90	*
1924	1,008	92	9.13	12.57	*
1925	91	0	0.00	12.00	*
1926	372	0	0.00	11.00	*
Total	5,950	356	5.98		
	Sawn Red Gum Ties. Treatment, 7 Lbs. Per Cu. Ft. 70/30 Creosote-Petroleum Mixture.				
1923	802	18	2.24	13.96	*
	Sawn Black Gum Ties. Treatment, 7 Lbs. Per Cu. Ft. 70/30 Creosote-Petroleum Mixture.				
1923	400	0	0.00	14.00	*
	Sawn Pacific Coast Douglas Fir Ties. Treatment, 7 Lbs. Per Cu.Ft. 70/30 Creosote-Petroleum Mixture.				
1923	101	7	6.93	13.68	*
	Hewn and Sawn White Fir Ties. Treatment, 7 Lbs. Per Cu.Ft. 70/30 Creosote-Petroleum Mixture.				
1923	332	18	5.42	13.88	*
	Hewn and Sawn Magnolia Ties. Treatment, 7 Lbs. Per Cu.Ft. 70/30 Creosote-Petroleum Mixture.				
1923	363	11	3.03	13.94	*

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for Treated Ties.

Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Sawn Beech Ties. Treatment, 7 Lbs. Per Cu. Ft. 70/30 Creosote-Petroleum Mixture.				
1923	187	4	2.14	14.00	*
	Sawn Bay Ties. Treatment, 7 Lbs. Per Cu. Ft. 70/30 Creosote-Petroleum Mixture.				
1923	194	1	0.52	13.97	*
	Hewn and Sawn Southern Yellow Pine Ties. Treatment, 8 Lbs. Per Cu.Ft. 50/50 Creosote-Petroleum Mixture.				
1924	9,267	23	0.25	13.00	*
1925	6,489	150	2.31	11.94	*
1926	8,179	258	3.15	10.93	*
1927	18,761	357	1.90	9.96	*
Total	42,696	788	1.85		
	Hewn and Sawn Oak Ties. Treatment, 8 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1924	603	45	7.46	12.90	*
1925	447	31	6.94	11.83	*
1926	333	33	9.91	10.84	17.46
1927	172	0	0.00	10.00	*
Total	1,555	109	7.01		
	Hewn and Sawn Gum Ties. Treatment, 8 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1924	375	4	1.07	12.95	*
1925	1,348	56	4.15	11.81	*
1926	4,276	184	4.30	10.90	*
1927	580	27	4.66	9.93	*
Total	6,579	271	4.12		
	Sawn Beech Ties. Treatment, 8 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1925	101	0	0.00	12.00	*

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for Treated Ties.

Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn Elm Ties. Treatment, 8 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1925	99	0	0.00	12.00	*
1926	102	0	0.00	11.00	*
Total	201	0	0.00		
	Hewn Bay Ties. Treatment, 8 Lbs. Per Cu. Ft. 50/50 Creosote-Petroleum Mixture.				
1925	99	0	0.00	12.00	*
1926	100	1	1.00	10.95	*
Total	199	1	0.50		
	Hewn and Sawn Southern Yellow Pine Ties. Treatment, 8 Lbs. Per Cu. Ft. 45/55 Creosote-Petroleum Mixture.				
1924	509	1	0.20	12.99	*
1925	1,365	4	0.29	12.00	*
1927	210	0	0.00	10.00	*
Total	2,084	5	0.24		
	Hewn and Sawn Western Yellow Pine Ties. Treatment, 8 Lbs. Per Cu. Ft. 45/55 Creosote-Petroleum Mixture.				
1924	714	8	1.12	12.94	*
1925	1,042	21	2.02	11.95	*
1926	3,765	12	0.32	10.99	*
1927	4,399	34	0.77	9.95	*
Total	9,920	75	0.76		
	Hewn and Sawn Gum Ties. Treatment, 8 Lbs. Per Cu. Ft. 45/55 Creosote-Petroleum Mixture.				
1924	99	0	0.00	13.00	*
	Sawn Pacific Coast Douglas Fir Ties. Treatment, 8 Lbs. Per Cu. Ft. 45/55 Creosote-Petroleum Mixture.				
1924	1,166	71	6.09	12.82	*
1925	2,583	39	1.51	11.90	*
1926	10,877	125	1.15	10.95	*
1927	6,713	40	0.60	9.83	*
Total	21,339	275	1.29		

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for Treated Ties.

Year Inserted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn Rocky Mountain Fir Ties. Treatment, 8 Lbs. per Cu. Ft. 45/55 Creosote-Petroleum Mixture.				
1925	194	2	1.03	11.98	*
1927	3,040	21	0.69	9.96	*
Total	3,234	23	0.71		
	Hewn and Sawn Corkbark Fir Ties. Treatment, 8 Lbs. Per Cu. Ft. 45/55 Creosote-Petroleum Mixture.				
1927	136	6	4.41	9.78	*
	Sawn Magnolia Ties. Treatment, 8 Lbs. Per Cu. Ft. 45/55 Creosote-Petroleum Mixture.				
1926	99	1	1.01	10.95	*
	Hewn and Sawn Balsam Ties. Treatment, 8 Lbs. Per Cu. Ft. 45/55 Creosote-Petroleum Mixture.				
1926	350	2	0.57	11.00	*
	Hewn Southern Yellow Pine Ties. Treatment, 8 Lbs. Per Cu. Ft. 25/75 Creosote-Petroleum Mixture.				
1924	999	2	0.20	13.00	*
1925	1,058	0	0.00	12.00	*
Total	2,057	2	0.10		
	Hewn Western Yellow Pine Ties. Treatment, 8 Lbs. Per Cu.Ft. 25/75 Creosote-Petroleum Mixture.				
1924	998	2	0.20	12.99	*
	Hewn Gum Ties. Treatment, 8 Lbs. Per Cu. Ft. 25/75 Creosote-Petroleum Mixture.				
1925	507	0	0.00	12.00	*

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

Year Inserted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn Southern Yellow Pine Ties. Treatment, 1/2 Lb. Zinc Chloride Plus 5 Lbs. 30/70 Creosote-Petroleum Mixture, Two-Movement.				
1922	600	56	9.33	14.92	*
1923	959	190	19.81	13.49	19.44
Total	1,559	246	15.78		
	Hewn and Sawn Western Yellow Pine Ties. Treatment, 1/2 Lb. Zinc Chloride Plus 5 Lbs. 30/70 Creosote-Petroleum Mixture, Two-Movement.				
1922	1,759	60	3.41	14.94	*
1923	940	22	2.34	13.96	*
1926	6,676	16	0.24	10.99	*
Total	9,375	98	1.05		
	Hewn and Sawn Red Oak Ties. Treatment, 1/2 Lb. Zinc Chloride Plus 5 Lbs. 30/70 Creosote-Petroleum Mixture, Two-Movement.				
1922	800	172	21.50	14.60	20.55
1923	424	24	5.66	13.95	*
Total	1,224	196	16.01		
	Hewn and Sawn White Oak Ties. Treatment, 1/2 Lb. Zinc Chloride Plus 5 Lbs. 30/70 Creosote-Petroleum Mixture, Two-Movement.				
1922	401	78	19.45	14.62	21.13
1923	141	44	31.21	13.52	17.50
Total	542	122	22.51		
	Hewn and Sawn Gum Ties. Treatment, 1/2 Lb. Zinc Chloride Plus 5 Lbs. 30/70 Creosote-Petroleum Mixture, Two-Movement.				
1922	800	14	1.75	14.97	*
1923	777	19	2.45	13.94	*
Total	1,577	33	2.09		

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

Year Inserted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Sawn Pacific Coast Douglas Fir Ties. Treatment, 1/2 Lb. Zinc Chloride Plus 5 Lbs. 30/70 Creosote-Petroleum Mixture, Two-Movement.				
1922	1,000	918	91.80	12.44	*
1923	300	102	34.00	13.37	17.28
Total	1,300	1,020	78.46		
	Hewn Rocky Mountain Fir Ties. Treatment, 1/2 Lb. Zinc Chloride Plus 5 Lbs. 30/70 Creosote-Petroleum Mixture, Two-Movement.				
1922	200	23	11.50	14.88	23.08
1923	200	2	1.00	13.98	*
Total	400	25	6.25		
	Sawn Beech Ties. Treatment, 1/2 Lb. Zinc Chloride Plus 5 Lbs. 30/70 Creosote-Petroleum Mixture, Two-Movement.				
1923	196	7	3.57	13.93	*
	Sawn Magnolia Ties. Treatment, 1/2 Lb. Zinc Chloride Plus 5 Lbs. 30/70 Creosote-Petroleum Mixture, Two-Movement.				
1923	208	0	0.00	14.00	*
	Hewn Southern Yellow Pine Ties. Treatment, 1/4 Lb. Dry Zinc Chloride and 8 Lbs. Petroleum. Zinc chloride Solution and Petroleum in Emulsion - One-Movement.				
1925	626	29	4.63	11.94	*
1926	197	2	1.02	10.98	*
Total	823	31	3.77		
	Hewn Southern Yellow Pine Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 8 Lbs. Petroleum. Zinc Chloride Solution and Petroleum in Emulsion - One-Movement.				
1925	682	58	8.50	11.87	*
1926	146	11	7.53	10.88	*
Total	828	69	8.33		

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

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Year Inserted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn Southern Yellow Pine Ties. Treatment, 3/4 Lb. Dry Zinc Chloride and 8 Lbs. Petroleum. Zinc Chloride Solution and Petroleum in Emulsion - One-Movement.				
1925	593	39	6.58	11.95	*
1926	227	11	4.85	10.98	*
Total	820	50	6.10		
	Hewn Oak Ties. Treatment, 1/3 Lb. Dry Zinc Chloride and 8 Lbs. Petroleum. Zinc Chloride Solution and Petroleum in Emulsion - One-Movement.				
1925	221	83	37.56	11.38	14.29
	Hewn Gum Ties. Treatment, 2/3 Lb. Dry Zinc Chloride and 8 Lbs. Petroleum. Zinc Chloride Solution and Petroleum in Emulsion - One-Movement.				
1925	230	18	7.83	11.91	*
	Hewn and Sawn Southern Yellow Pine Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum - Two-Movement.				
1922	600	244	40.67	14.39	17.44
1923	800	55	6.88	13.80	*
1924	313	49	15.65	12.86	18.84
Total	1,713	348	20.32		
	Hewn and Sawn Western Yellow Pine Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum-Two-Movement.				
1922	1,398	27	1.93	14.96	*
1923	802	30	3.74	13.95	*
Total	2,200	57	2.59		
	Hewn and Sawn Red Oak Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum - Two-Movement.				
1922	801	346	43.20	14.16	17.24
1923	390	69	17.69	13.63	20.00
1924	208	83	39.90	12.28	15.29
Total	1,399	498	35.60		

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

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Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn White Oak Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum - Two-Movement.				
1922	399	123	30.83	14.38	18.75
1923	200	65	32.50	12.86	17.28
Total	599	188	31.39		
	Hewn and Sawn Gum Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum - Two-Movement.				
1922	796	292	36.68	14.12	18.07
1924	296	30	10.14	12.79	20.63
Total	1,092	322	29.49		
	Hewn and Sawn Red Gum Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum - Two-Movement.				
1923	392	20	5.10	13.81	*
	Sawn Black Gum Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 lbs. Petroleum - Two-Movement.				
1923	191	0	0.00	14.00	*
1924	272	30	11.03	12.86	20.31
Total	463	30	6.48		
	Sawn Pacific Coast Douglas Fir Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum - Two-Movement.				
1922	998	822	82.36	11.03	12.71
1923	200	100	50.00	13.36	15.22
Total	1,198	922	76.96		
	Hewn Rocky Mountain Fir Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum - Two-Movement.				
1922	400	16	4.00	14.96	*
	Sawn Beech Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum - Two-Movement.				
1923	199	10	5.03	13.94	*

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Sawn Magnolia Ties. Treatment, 1/2 Lb. Dry Zinc Chloride and 5 Lbs. Petroleum - Two-Movement.				
1923	200	0	0.00	14.00	*
	Hewn & Sawn Western Yellow Pine Ties. Treatment, 1/2 Lb. Dry Zinc chloride and 8 Lbs. Petroleum - Two-Movement.				
1926	2,543	3	0.12	10.99	*
	Hewn and Sawn Southern Yellow Pine Ties. Treatment - 5 Lbs. Creosote - Rueping.				
1904	1,448	1,439	99.38	22.43	*
1905	1,949	1,904	97.69	16.85	*
1906	43,720	41,220	94.28	21.39	*
1907	19,078	17,780	93.20	18.40	*
1908	24,318	22,378	92.02	19.17	*
1909	18,380	16,632	90.49	18.19	22.22
1910	91,506	48,562	53.07	23.74	28.72
1911	15,368	8,199	53.35	22.44	27.66
1912	11,439	8,339	72.90	21.06	22.73
1913	274,169	54,381	19.83	22.80	33.33
1914	31,522	17,583	55.78	18.71	23.96
1915	5,247	3,996	76.16	16.98	19.64
1916	4,581	1,836	40.08	18.97	24.71
1917	19,534	5,079	26.00	18.92	26.32
1918	11,266	5,496	48.78	17.39	20.88
1919	15,183	3,420	22.53	16.70	24.32
1920	2,946	1,504	51.05	14.61	18.28
1921	2,729	851	31.18	14.86	20.00
1922	8,434	2,359	27.97	13.95	19.23
1923	5,245	1,049	20.00	13.50	19.44
1924	364	46	12.64	12.75	19.70
1925	70	19	27.14	11.34	15.58
Total	608,496	264,072	43.40		
	Hewn and Sawn Western Yellow Pine Ties. - Treatment, 5 Lbs. Creosote - Rueping.				
1908	1,440	1,272	88.33	18.50	23.39
1909	5,338	3,802	71.23	20.83	25.93
1910	3,586	3,069	85.58	18.66	22.13
1911	2,437	2,075	85.15	10.84	21.49
1912	680	581	85.44	15.71	20.66
1913	1,711	1,213	70.89	18.63	22.22
1914	2,570	1,324	51.52	18.98	24.47
1915	377	195	51.72	17.92	23.40
1916	4,409	1,527	34.63	19.45	25.61
1917	5,235	1,220	23.30	18.58	27.03

(This table continued on following page, No. 13.)

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn Western Yellow Pine Ties. Treatment, 5 Lbs. Creosote - Rueping (Con't) From Page No. 12.)				
1918	455	134	29.45	17.46	24.36
1920	2,269	132	5.82	16.68	*
1921	312	50	16.03	15.47	23.19
1922	2,101	185	8.85	14.84	*
1923	765	19	2.48	13.99	*
Total	33,685	16,798	49.87		
	Hewn and Sawn Oak Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1906	113	112	99.12	21.50	*
1909	3,287	2,549	77.55	21.01	24.56
1910	4,571	3,969	86.83	20.05	21.95
1911	4,784	3,407	71.22	19.95	24.07
1912	2,354	1,507	64.02	20.91	24.51
1913	1,445	1,192	82.49	20.67	20.34
1914	2,074	1,087	52.41	20.39	24.47
1915	1,743	864	49.57	18.36	23.91
1916	3,866	2,260	58.46	19.04	21.43
1917	3,608	1,466	40.63	18.27	23.26
1918	1,845	553	29.97	18.26	27.14
1919	673	518	76.97	13.56	15.93
1920	176	61	34.66	14.24	20.73
1921	118	12	10.17	15.83	25.40
1922	914	201	21.99	14.57	20.55
1923	1,435	379	26.41	13.16	18.42
1924	934	108	11.56	12.75	20.00
1925	226	20	8.85	11.73	*
Total	34,166	20,265	59.31		
	Hewn and Sawn Red Oak Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1907	52	51	98.08	15.87	*
1911	506	239	47.23	22.63	28.89
1913	321	160	49.84	23.17	26.09
1917	4,347	435	10.01	19.65	31.75
1918	2,769	151	5.45	18.87	*
1922	1,344	66	4.91	14.92	*
1923	792	16	2.02	13.90	*
Total	10,131	1,118	11.04		

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

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Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn White Oak Ties. Treatment, 5 Lbs. Creosote-Rueping.				
1911	375	250	66.67	23.55	24.76
1922	400	2	0.50	15.00	*
1923	391	1	0.26	14.00	*
Total	1,166	253	21.70		
	Hewn and Sawn Gum Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1907	2,282	2,044	89.57	22.29	23.81
1908	842	575	68.29	21.74	27.62
1909	1,805	413	22.88	25.26	37.84
1910	13,135	800	6.09	26.85	*
1911	2,591	1,605	61.95	22.05	25.74
1912	380	322	84.74	20.16	20.66
1913	906	700	77.26	21.00	21.24
1914	2,682	1,150	42.88	21.55	26.44
1917	819	194	23.69	19.12	26.67
1918	678	383	56.49	15.87	19.79
1920	847	334	39.43	15.43	20.24
1921	1,920	231	12.03	15.57	24.62
1922	4,077	435	10.67	14.64	23.44
1923	1,433	204	14.24	13.69	20.90
1924	194	25	12.89	12.42	19.70
1926	330	0	0.00	11.00	*
Total	34,921	9,415	26.96		
	Hewn and Sawn Red Gum Ties. Treatment, 5 Lbs. Creosote-Rueping.				
1923	802	10	1.25	13.96	*
1924	102	2	1.96	12.90	*
Total	904	12	1.33		
	Hewn & Sawn Black Gum Ties. Treatment, 5 Lbs. Creosote-Rueping.				
1923	386	6	1.55	13.96	*
	Sawn Pacific Coast Douglas Fir Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1910	13,009	12,583	96.61	16.71	*
1911	271	258	95.20	15.46	*
1915	1,974	607	30.75	20.76	27.50
1916	1,650	735	44.55	19.48	23.86
1920	738	33	4.47	16.78	*
1921	422	28	6.64	15.53	*
1922	1,374	63	4.59	14.91	*
1923	458	33	7.21	13.50	*
Total	19,896	14,325	72.00		

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.

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Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn Rocky Mountain Fir Ties. Treatment 5 Lbs. Creosote - Rueping.				
1923	200	0	0.00	14.00	*
	Hewn White Fir Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1923	200	1	0.50	14.00	*
	Sawn Beech Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1911	307	99	32.25	23.09	32.50
1912	1,914	1,188	61.81	22.75	24.75
1923	200	3	1.50	14.00	*
Total	2,421	1,285	53.08		
	Hewn and Sawn Balsam Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1926	369	1	0.27	10.99	*
	Hewn and Sawn Cottonwood Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1923	150	2	1.33	13.91	*
	Hewn Ash Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1907	240	238	99.17	18.12	*
	Sawn Bay Ties. Treatment, 5 Lbs. Creosote - Rueping.				
1923	201	8	3.98	13.83	*
	Sawn Magnolia Ties. Treatment, 5 Lbs. Creosote-Rueping.				
1923	398	28	7.04	13.82	*
1925	86	0	0.00	12.00	*
Total	484	28	5.79		

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for Treated Ties.

Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Hewn and Sawn Southern Yellow Pine Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1922	600	24	4.00	14.96	*
1923	523	29	5.54	13.94	*
Total	1,123	53	4.72		
	Hewn and Sawn Western Yellow Pine Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1922	1,600	17	1.06	14.97	*
1923	800	14	1.75	13.98	*
1924	148	1	0.68	12.97	*
Total	2,548	32	1.26		
	Hewn and Sawn Red Oak Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1922	1,200	15	1.25	14.98	*
1923	31,262	417	1.33	13.97	*
Total	32,462	432	1.33		
	Hewn and Sawn White Oak Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1922	399	5	1.25	14.99	*
1923	200	10	5.00	13.82	*
Total	599	15	2.50		
	Hewn and Sawn Gum Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1922	1,200	58	4.83	14.93	*
	Hewn and Sawn Red Gum Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1923	770	15	1.95	13.97	*
	Hewn and Sawn Black Gum Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1923	400	3	0.75	13.97	*

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for Treated Ties.

Atchison, Topeka & Santa Fe Railway—Continued

Year Inserted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track To 1-1-38	Expected Average Life #
	Sawn Pacific Coast Douglas Fir Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1923	1,000	29	2.90	14.95	*
1925	200	1	0.50	14.00	*
Total	1,200	30	2.50		
	Sawn Beech Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1923	190	10	5.26	13.84	*
	Hewn White Fir Ties. Treatment, 7 Lbs. Creosote-Rueping.				
1923	200	1	0.50	13.98	*
	Hewn Rocky Mountain Fir Ties. Treatment 7 Lbs. Creosote - Rueping.				
1923	198	7	3.54	13.87	*
	Sawn Bay Ties. Treatment, 7 Lbs. Creosote - Rueping.				
1923	200	3	1.50	13.93	*
	Sawn Magnolia Ties. Treatment, 7 Lbs. Creosote-Rueping.				
1923	400	7	1.75	13.98	*

Based on Forest Products Laboratory Curve.
* Percent renewed is beyond the limits of the Forest Products Laboratory Curve for Treated Ties.

Reading Company

Tabulation Showing Actual Performance to July 7, 1938, in Track, and Estimated Total Life Based on Tie-Life Curve of the Forest Products Laboratory at Madison, Wisconsin, of Ties in Test Tracks of the Philadelphia and Reading Railroad, Treated with Creosote-Gas Oil Mixture, and Creosote-Petroleum Mixture.

Year Inserted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track to 7-7-38	Expected Average Life #
	Hewn Sap Pine Ties. Treatment, 10 Lbs. Per Cu. Ft. + 30/70 Creosote-Gas Oil Mixture - Full Cell.				
1925	100	0	0.00	12.00	*
	Sawn Birch, Beech and Maple Ties. Treatment, 9.90 Lbs. Per Cu. Ft. 30/70 Creosote-Gas Oil Mixture - Full Cell.				
1925	100	0	0.00	12.00	*
One tie showing evidence of decay in 1937, still in service. This tie split by derailment.					
	Hewn and Sawn Red Oak Ties. Treatment, 8.69 Lbs. Per Cu. Ft. 30/70 Creosote-Gas Oil Mixture - Full Cell.				
1925	100	0	0.00	12.00	*
	Hewn Sap Pine Ties. Treatment, 9.77 Lbs. Per Cu. Ft. 30/70 Creosote-Petroleum Mixture - Full Cell.				
1925	100	0	0.00	12.00	*
	Sawn Birch, Beech and Maple Ties. Treatment, 9.52 Lbs. Per Cu. Ft. 30/70 Creosote-Petroleum Mixture-Full Cell.				
1925	101	0	0.00	12.00	*
Three ties showing evidence of decay in 1937, still in service in 1938.					
	Sawn Red Oak Ties. Treatment, 9.44 Lbs. Per Cu. Ft. 30/70 Creosote-Petroleum Mixture - Full Cell.				
1925	100	0	0.00	12.00	*

Based on Forest Products Laboratory Curve.
* Percent Renewed is beyond the limits of the Forest Products Laboratory Curve for treated ties.
+ When stating the percentage of creosote-petroleum mixtures, in this report, the percentage of creosote is given first.

Tabulation Showing Actual Performance to January 1, 1939, in Track, and Estimated Total Life Based on Tie-Life Curve of the Forest Products Laboratory at Madison, Wisconsin, of Ties in Test Tracks of the Northern Pacific Railway Company, Treated with Creosote, Creosote-Petroleum Mixture, and Untreated.

Year In-serted	Original Number Inserted	Total Removed	Percent Removed	Average Life In Track to 1-1-39	Expected Average Life #
	Ties Placed Out-of-Face Near Grassy Point, Duluth				
	Hewn and Sawn White Oak Ties - Untreated.				
1922	100	76	76.00	12.94	*
	Hewn and Sawn Birch Ties - Treatment, 6.25 Lbs. Creosote - Lowry.				
1922	98	0	0.00	16.00	*
	Hewn and Sawn Birch Ties. - Treatment, 7 Lbs. 50/50 Creosote-Petroleum Mixture - Lowry.				
1922	101	0	0.00	16.00	*
	Hewn and Sawn Maple Ties - Treatment, 6.25 Lbs. Creosote - Lowry.				
1922	101	0	0.00	16.00	*
	Hewn and Sawn Maple Ties - Treatment, 7 Lbs. 50/50 Creosote-Petroleum Mixture - Lowry.				
1922	100	0	0.00	16.00	*
	Hewn and Sawn Red Oak Ties - Treatment, 6.25 Lbs. Creosote - Lowry.				
1922	100	0	0.00	16.00	*
	Hewn and Sawn Red Oak Ties - Treatment, 7 Lbs. 50/50 Creosote-Petroleum Mixture - Lowry.				
1922	100	0	0.00	16.00	*
	Ties Placed Out-of-Face near Plateau, Montana				
	Hewn and Sawn White Oak Ties - Untreated.				
1923	120	120	100.00	10.50	*
	Hewn and Sawn Birch Ties. Treatment - 6.25 Lbs. Creosote - Lowry.				
1923	101	0	0.00	15.00	*
	Hewn and Sawn Birch Ties. Treatment - 7 Lbs. 50/50 Creosote-Petroleum Mixture - Lowry.				
1923	100	0	0.00	15.00	*
	Hewn and Sawn Maple Ties. Treatment - 6.25 Lbs. Creosote - Lowry.				
1923	101	0	0.00	15.00	*
	Hewn and Sawn Maple Ties. Treatment - 7 Lbs. 50/50 Creosote-Petroleum Mixture - Lowry.				
1923	101	10	10.00	15.00	21.43
	Hewn and Sawn Red Oak Ties. Treatment, 6.25 Lbs. Creosote - Lowry.				
1923	100	0	0.00	15.00	*
	Hewn and Sawn Red Oak Ties. Treatment, 7 Lbs. 50/50 Creosote-Petroleum Mixture - Lowry.				
1923	100	0	0.00	15.00	*

Based on Forest Products Laboratory Curve.
* Percent Renewed is beyond the limits of the Forest Products Laboratory Curve for Treated Ties.

which have not been in track at least ten years. Groups of less than 50 ties have also been excluded.

Because of the large number of ties included in these tabulations, it has been impossible to inspect all failed ties removed from track to determine the reasons for failure. However, during the past years some of the ties from these test tracks, and in addition, a large number of ties of the same kinds from other than test tracks, have been inspected. In general, such inspections indicate that in the creosote and creosote-petroleum ties, less than 5 percent of the failures are primarily due to decay. About 90 percent of the failures are due to mechanical wear, which includes spike killing, shattering and splitting, and plate cutting, and in these, decay is sometimes a secondary cause of failure, gaining entrance because of spike killing, large checks, splits, and plate cutting. Something like 5 percent of the removals are due to burned and broken ties, and derailments. Approximately 65 percent of the straight zinc-chloride treated ties inspected failed because of decay, about 30 percent because of shattering and splitting, and the remainder because of burned and broken ties, and derailments.

The report is offered as information with the recommendation that the subject be continued.

Appendix E

(5) DESTRUCTION BY TERMITES AND POSSIBLE WAYS OF PREVENTION

Dr. Hermann von Schrenk, Chairman, Subcommittee; Wm. G. Atwood, E. A. Craft, F. D. Mattos, F. B. Robins, W. A. Summerhays.

In the Proceedings of the AREA, Vol. 34, page 483, 1933, and, furthermore, in the Proceedings, Vol. 39, page 290, 1938, the committee described an experiment for testing the efficiency of various soil poisons with reference to termites.

It has been found in late years that it is not always possible to employ the structural methods recommended by the government and endorsed by this committee. There are many buildings which practically rest on the ground and where it is impossible to apply termite shields or to repair the top of the foundation wall or to put in treated timbers. It is very desirable, therefore, to find some kind of chemical application which might be put into the soil next to buildings or under floors close to the ground, which would poison or repel termite attacks. In considering the application of these soil poisons, the committee wants to make it very clear that it still recommends structural repairs of buildings attacked by termites or structural methods for protecting against termites in the case of new buildings as the principal method of guarding against the ravages of these insects. The committee recognizes, however, that the use of a successful soil poison might be a valuable adjunct in many cases.

To Make Further Tests

In the first series of tests with 22 soil poisons, only one compound kept termites from eating any of the treated posts. This is a rather expensive material. With many other substances available, not included in the first test, the committee has carefully gone over other possible soil poisons and decided to initiate a second series of soil poison tests.

It is planned to carry out these tests essentially in the same manner as was done in the first test, namely, to use two-by-four sticks driven into the ground in a region

where termite attack is extremely probable. The results at Florissant, Mo., obtained in the first test show termites present over the entire area, and it was therefore decided to carry out the second test on the same piece of land, but at some distance from the first lot to avoid any possible residual effects of the poisons put into the ground for the first test. Sticks, two inches by four inches, each 2 feet long, will be used. In this second test at least six pieces will be used for each one of the compounds. A larger number of controls, or untreated pieces, have been provided than was the case in the first test. After serious consideration, it was decided to install the second test early in March, 1939, so that when the chemical applications are made it will be at a time when the termites are just beginning to work. The committee hopes that the experiment will have started at the time of the annual convention. At this time a brief outline of the materials to be tested will be given. Attention is called to the following high-spots:

1. A number of pressure-treated pieces will be placed. These include such compounds as zinc chloride, chromated zinc chloride, Wolman salts (Tanalith U), Celcure-Sol, Permatol "A" (pentachlorphenol), Pinola.

2. The successful results of the first series with trichlorbenzene led the committee to include in this second series not only a repetition of the 100 percent trichlorbenzene application, but also a considerable number of dilutions with petroleum, which might seem desirable, due to the high initial cost of 100 percent of the compound.

3. Included in the trichlorbenzene series are a number of posts which will be treated with two concentrations, using larger quantities of dilutions with petroleum to determine whether an application at some distance from the posts will have any effect.

4. A number of new compounds are included. Some of these will be applied to the test pieces by regular pressure treatment, some by dipping, and some applied to the soil. These include Pinola (a southern pine product), Celcure-Sol (an English preparation consisting largely of cupric chromate), and Permatol "A" (a compound which has shown high toxic values).

Compounds to Be Tested

In the following the term "soil poison" is used to mean that the particular compound used is poured on the ground immediately in touch with the two-by-four posts. The following compounds are to be tested:

1. *Pinola:* One lot of pieces soaked in a vat 24 hours; another lot treated with Pinola used as a soil poison; and 2 series of untreated control pieces.

2. *Chromated Zinc Chloride:* Pieces pressure treated and an equal number of untreated control pieces.

3. *Zinc Chloride:* Pieces treated by the open tank process to refusal.

4. *Trichlorbenzene:* 100 percent trichlorbenzene used as a soil poison.

5. *Trichlorbenzene:* 80 percent trichlorbenzene and 20 percent kerosene used as a soil poison.

6. *Trichlorbenzene:* 50 percent trichlorbenzene and 50 percent kerosene used as a soil poison.

7. *Trichlorbenzene:* 25 percent trichlorbenzene and 75 percent kerosene used as a soil poison.

8. *Trichlorbenzene:* 10 percent trichlorbenzene and 90 percent kerosene used as a soil poison.

9. 50 percent *distillate coal tar creosote* and 50 percent *kerosene* to be used as a soil poison.

In series 4 to 9, inclusive, there are two sets of untreated control pieces.

10. *Antimite:* (This is the old Wolman Tanalith, without chromium salts): 4 percent solution used as a soil poison, and an equal number of untreated control pieces.

11. *Wolman Salts* (Tanalith U): 4 percent solution used as a soil poison; pieces pressure treated; and an equal number of untreated control pieces.

12. *Celcure-Sol:* Pieces to be pressure treated; dipped; treated by natural vacuum process; and untreated controls.

13. *Trichlorbenzene:* 500 cc. of 10 percent trichlorbenzene, and 90 percent kerosene poured next to the posts.

14. *Trichlorbenzene:* 1000 cc. of 10 percent trichlorbenzene and 90 percent kerosene poured in a 20-in. circle around the posts, and untreated control pieces.

15. *Trichlorbenzene:* 2000 cc. of 10 percent trichlorbenzene and 90 percent kerosene poured in a 20-in. circle around the posts.

16. *Trichlorbenzene:* 500 cc. of 5 percent trichlorbenzene and 95 percent kerosene poured next to the posts.

17. *Trichlorbenzene:* 1000 cc. of 5 percent trichlorbenzene and 95 percent kerosene poured in a 20-in. circle around the the posts.

18. *Trichlorbenzene:* 2000 cc. of 5 percent trichlorbenzene and 95 percent kerosene poured in a 20-in. circle around the posts.

19. *Permatol "A"* (5 percent pentachlorphenol 5 percent non-volatile solvent, 90 percent petroleum distillate): pieces pressure treated; dipped, used as a soil poison; and untreated control pieces.

20. *Hooker's "Solvent T":* Used as a soil poison, and an equal number of untreated control pieces.

21. *Scafoil* (a Belgian preparation which in many respects is like distillate creosote): Used as a soil poison; pieces dipped.

The committee decided that in this new series much more attention should be paid to the untreated control pieces. Great care has been taken in this new series to use "two-by-fours" of considerable length and to cut these into two-foot pieces, a number of which were included in a series to be treated, and a number of which were left as controls; to illustrate: In the series of various dilutions of trichlorbenzene and kerosene, six 16-ft. sticks were cut into 8 lengths each. The first piece from each "two-by-four" was kept as a control; Pieces No. 2 were used for 100 percent trichlorbenzene; No. 3 for 80 percent trichlorbenzene and 20 percent kerosene; No. 4 for controls; No. 5 for 50 percent trichlorbenzene and 50 percent kerosene; No. 6 for 25 percent trichlorbenzene and 75 percent kerosene; No. 7 for 10 percent trichlorbenzene and 90 percent kerosene; and No. 8 for 50 percent creosote and 50 percent kerosene. In the same way, the rest of the material was handled, always making sure that that for every one of the series the controls were cut from the same pieces as the ones to be soil-treated or pressure-treated.

Your committee wishes to express its appreciation hereby to the following for contributions of material, chemicals, or treatment:

Wiles-Chipman Lumber Co. of St. Louis, for untreated "two-by-fours" donated for this test, as well as the Wolman pressure treated pieces;

Angelina County Lumber Co., of Keltys, Tex., for pressure treated chromated zinc chloride pieces and controls.

Glidden Company for "two-by-fours", Pinola, and treatment of these pieces;

Monsanto Chemical Co., for Permatol "A" pressure treatment, and material to be used for soil poison;

Celcure Southern Corporation, for "two-by-fours", pressure treated and dipped with Celcure-Sol;

Hooker Electrochemical Co., for trichlorbenzene;
American Lumber & Treating Co., for Wolman salts to be used as a soil poison;
Antimite Co., for Antimite to be used as a soil poison.

Termite Attacks Reported

The committee has kept track of attacks by termites in various parts of the United States, in particular with reference to railroad structures. A large number of cases have been reported, but they are all about of the same types as have hitherto been described. One railroad had four of its stations attacked by termites, and in all cases reconstruction was effected by the use of heavily creosoted timbers, floor joists, subfloors, etc., which, it is expected, will effectively prevent any further destruction.

The reports of attacks have extended all the way across the United States. One of the most interesting pieces of research work during the past year was conducted by Miss Olive Falls, under the auspices of the University of Minnesota, in connection with the appearance of termites in considerable force in southwest Minnesota. The survey was made from St. Paul south and west, and extended into eastern South Dakota and northern Iowa. The principal point of attack was found at Luverne, Minn., where these insects seem to be confined to an area of less than two square miles. One of the interesting points was the manner in which termites attacked living vegetation. Miss Falls found no evidence that the termites are spreading northward or that they are an importation. She calls attention to the fact that the survey made at this time, and in 1930 and 1931, shows that the form present is "a distinctly temperate genus, and there is strong evidence that termites have been in temperate regions of the United States for many million years. There are, also, indications that the termite infestations at these points are of as long standing as the infestations in other sections of the United States."

It is expected that the results of Miss Falls' investigations will be published shortly, and when the publication is issued your committee will give the citation so that any one interested may get a copy.

Another interesting event was the extensive discussion of termites and their control at the meeting of the National Pest Control Association at Omaha, Neb., in October. This was a round-table discussion dealing with subterranean termites and their control. The use of termite shields and properly treated lumber was again thoroughly emphasized by all those who took part in this discussion.

The Illinois Central System is making some tests with various compounds applied in the form of two heavy brush coats to pieces of sap pine boards 1 in. by 4 in. by 24 in., kiln dried and dressed on four sides. The earliest installations were made in 1937, and others have been made from time to time. All of these tests are being made in the vicinity of Memphis, Tenn. No specific results are available to date, but it is anticipated that matters of interest will develop in the course of another year or two.

The report is presented as information with the recommendation that the subject be continued.

Appendix F

(6) EFFECT ON PRESERVATIVE IN TREATED TIES IN TRACK DUE TO BLOWING OFF LOCOMOTIVES ON LINE OF ROAD,

Collaborating with Committee 13—Water Service, Fire Protection and Sanitation; 22, Economics of Railway Labor, and 27, Maintenance of Way Work Equipment

C. S. Burt, Chairman, Subcommittee; G. B. Campbell, H. R. Duncan, W. R. Goodwin, L. B. Holt, R. S. Hubley, R. P. Hughes, A. J. Loom, L. J. Reiser, T. H. Strate.

The 1938 report of this committee included a full description of track and laboratory experimental work completed by the Nickel Plate and the Chesapeake and Ohio Railroads in connection with this study.

Since that time careful observation of the effect of blow-off of locomotives on creosoted ties in track has continued, and further practical field experiments have been carried on. One such test on the Santa Fe has been finished and there follows a brief outline of procedure together with results of the findings of that test.

In order to study the effect on ties of underneath blow-off of locomotives, 14 ties were removed from the Santa Fe tracks in September, 1935. Of these ties, seven were from locations where locomotives blow off frequently; and seven were not subjected to blow-off, but were of corresponding woods, treatments, ages, and from the same general vicinity. The ties are listed in the following table:

Station Shipped From	*Tie Number*	*Date Tie Inserted*	*Treatment*	*Kind of Wood*	*If Subjected to Blow-off*
La Junta	1	1929	B	Sawn western yellow pine	Yes
La Junta	1–A	1929	B	Sawn western yellow pine	No
La Junta	2	1931	A	Hewn oak	Yes
La Junta	2–A	1931	A	Hewn oak	No
Syracuse	3	1920	Creo.	Hewn southern pine	Yes
Syracuse	3–A	1920	Creo.	Hewn southern pine	No
Syracuse	4	1927	B	Sawn western yellow pine	Yes
Syracuse	4–A	1927	B	Sawn western yellow pine	No
Syracuse	5	1928	B	Hewn western yellow pine	Yes
Syracuse	5–A	1928	B	Hewn western yellow pine	No
Las Vegas	6	1930	B	Hewn western yellow pine	Yes
Las Vegas	6–A	1930	B	Hewn western yellow pine	No
Las Vegas	7	1930	A	Hewn gum	Yes
Las Vegas	7–A	1930	A	Hewn gum	No

Note: Treatments—
A—50% Creosote—50% Petroleum.
B—45% Creosote—55% Petroleum.
Creo.—100% Creosote.

The illustrations appearing with this report show each of these ties in track just prior to their removal in September, 1935.

As shown in Fig. 1, a section was taken from the top of each of these ties, each section being ½ in. thick, the width that of the tie, and 2 ft. long—1 ft. each side of the middle of the tie. Any pitchlike coating present was scraped off and discarded. The wood was cut into small chips and extracted with sulphuric ether for 48 hours in a Soxhlet extractor. After extraction, the resins were removed by the solvent action of potassium carbonate. After drying over sodium sulphate, the ether was removed by dis-

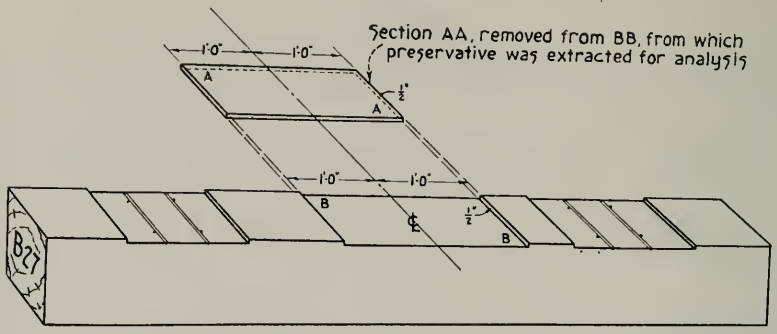

FIG. 1.—Sketch Showing Method of Cutting Sections from Ties for Extraction of Preservative for Analysis.

tillation over a water bath at 100 deg. C. The remaining extract was transferred to a weighed micro-distilling flask and heated to 210 deg. C. All subsequent data are based on the oil from the extract remaining at 210 deg. C. The micro-flask referred to was devised by E. O. Rhodes and described in the American Wood-Preservers' Association Proceedings for 1934 in the article on "Creosote Permanence-Toxicity Relationships".

Before carrying out the work, as outlined above, on the sections from the test ties, several distillations were made with the micro-flask and with the American Wood-Preservers' Association standard flask to make a comparison of the results from the two flasks. These results were obtained on a sample of straight creosote:

Average for 3 distillations *Degrees centigrade*	*Standard Flask Percents*	*Micro-Flask Percents*
Up to 210	.00	2.20
210 to 235	9.67	18.70
235 to 270	26.93	19.73
270 to 315	18.33	18.37
315 to 355	20.33	19.10
Residue	24.77	21.33

Using a sample of 50–50 mixture of creosote and petroleum gave these results:

Average for 2 disillations *Degrees centigrade*	*Standard Flask Percents*	*Micro-Flask Percents*
Up to 210	0.40	0.90
210 to 235	2.85	8.55
235 to 270	13.00	11.70
270 to 315	14.15	11.60
315 to 355	15.55	17.30
Residue	53.85	49.10

The comparative results as given above show the micro method gives too high a result on the fraction to 235 deg. C., and approximately 5 percent lower residue than the standard method.

Determinations made on the extracts from the ties are given in the table.

DETERMINATIONS MADE ON EXTRACTS FROM THE TIES

Tie No.	Years in Track	Subjected to Blow-Off	Absorption in ½" Sect. Lb. cu. ft.	Specific* Gravity At 100–60°F.	Distillation				
					210–235°	235–270°	270–315°	315–355°	Residue
					Percentages				
1	6	Yes	3.35	0.990	3.03	5.04	10.03	26.95	50.01
1-A	6	No	3.52	0.977	2.80	6.39	10.00	26.08	52.80
2	4	Yes	2.59	1.015	1.61	6.00	9.96	27.00	53.70
2-A	4	No	2.67	1.020	0.41	6.44	11.07	26.38	54.20
3	15	Yes	2.17	1 095	0.82	3.69	12.33	31.13	50.53
3-A	15	No	2.17	1.089	1.03	2.66	8.95	23.43	62.52
4	8	Yes	4.11	0.982	2.60	4.38	11.12	29.13	50.41
4-A	8	No	3.43	0.992	0.31	3.70	8.64	22.76	62.26
5	7	Yes	1.60	0.997	2.96	4.78	10.54	25.35	54.90
5-A	7	No	3.27	.978	2.44	7.33	10.54	25.31	52.83
6	5	Yes	2.08	1.010	2.69	3.90	10.71	25.91	55.59
6-A	5	No	6.23	0.982	1.00	2.33	9.87	25.59	59.55
7	5	Yes	3.59	0.995	1.79	9.34	15.24	29.27	42.94
7-A	5	No	7.30	1.002	2.85	6.81	10.73	21.40	57.20

* Calculated from weight of preservative extracted.

Of the 14 ties tested 4 of the mixture-treated ties were treated at Somerville, namely ties 2, 2-A, 7, and 7-A. The average analysis of the creosote-petroleum mixture used at that time should give a distillation approximately as given below, to which may be compared the average of the analyses of mixture extracted from the above 4 ties:

	Probable Mixture Used Standard Method	Average for Four ties Micro Method
Specific Gravity at 100–60 deg. F.	0.990	1.008
Distillation—	Percents	Percents
Up to 235 deg. C.	7.7	1.67
235 to 270 deg. C.	14.8	7.15
270 to 315 deg. C.	14.2	11.75
315 to 355 deg. C.	17.2	26.01
Residue	47.0	52.01

Likewise, eight of the mixture treated ties were treated at Albuquerque: Ties 1, 1–A, 4, 4–A, 5, 5–A, 6, and 6–A. The average of the analyses of the creosoted and petroleums used during the time of their treatments should give a distillation approximately as given below. This may be compared with the average analyses of mixture extracted from the eight ties mentioned.

	Probable Mixture Used Standard Method	Average for Eight Ties Micro Method
Distillation:	Percents	Percents
Specific Gravity at 100/60 deg. C.	0.982	0.988
Up to 235	6.7	2.24
235 to 270	11.6	4.73
270 to 315	17.2	10.18
315 to 355	17.7	25.88
Residue	46.8	54.79

There is quite a variation in the absorptions in the ½-in. middle section of the test ties, which of course is to be expected. The average is lower for the ties subjected to blow-off, being 2.78 lb. per cu. ft. as compared to an average of 4.08 lb. per cu. ft. for the ties not subjected to blow-off. Although there is this difference now in the absorp-

tions of the tie sections tested, the absorptions at the time of treatment are not known. It is merely assumed that the absorptions were the same, namely 8 lb. per cu. ft. for the entire tie.

In this connection it may be mentioned that ordinarily a larger percentage of mixture-treated ties develop a pitchlike coating. This coating can be observed on the samples from the cross-sections from the top ½-in. of ties 1–A, 4–A, 5–A and 6–A, which were not subjected to blow-off. These are shown in Fig. 2. On the ties subjected to blow-off, the coating either was not formed or was destroyed because of the action of the steam and hot water softening or washing any oil or oily coating from the tie.

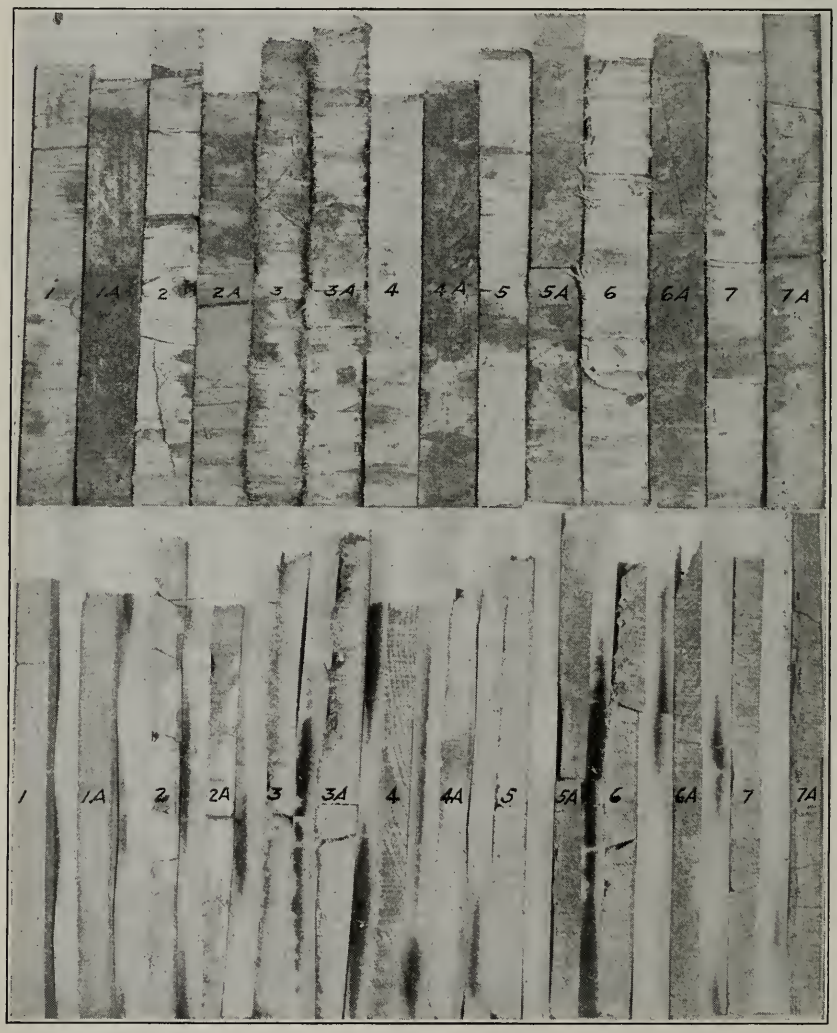

Fig. 2.—Top and Side Views of 1-in. Strips Cut from ½-in. by 2-ft. Sections Taken from Tops of Ties, as Shown in Fig. 1.

There is generally very little difference in the gravities of the oils extracted from the ties subjected to blow-off, and those not subjected.

The residues above 355 deg. C. are lower for the ties subjected to blow-off than for the corresponding ties not subjected, the averages being 51.15 percent and 57.34 percent respectively. This difference in the amount of residue is probably caused by the conditions resulting in the absence or presence of the pitchlike coating referred to above. The loss of preservative from the ties subjected to blow-off seems to be more nearly a removal of the whole oil. Any evaporation of some constituents of the preservative at the surface of a tie would leave the heavier constituents, but if the heavier constituents are removed by the steam and hot water from the locomotive blow-off, more preservative would probably move to the surface. In time, no doubt some limit would be reached, beyond which there would be no flow of preservative to the surface.

The top center sections of the ties subjected to blow-off had the appearance of being scoured and scrubbed. All these ties at the time examined, were quite sound throughout and each would, no doubt, have served for several years to come.

FIG. 3.—Hewn Creosoted Gum Ties Inserted in 1929. Note Bleached Appearance in Center of Track Caused by Steam from Blowing Off Locomotives.

Tie No. 3 (Creo. hewn southern pine, 1920) was the poorest as to surface condition. Its top center section was covered with loosened fibers of the wood. There was little binder holding the wood fibers together. It is believed the binder was destroyed by the solvent action of the alkalies in the boiler water.

From the standpoint of removal of preservative only, comparative results indicate no particular harmful effects from exposure to blow-off. A small quantity of this preservative is removed from the outer surface of the wood but it is believed that sufficient preservative remains to protect the tie for many years, however, it is thought that some

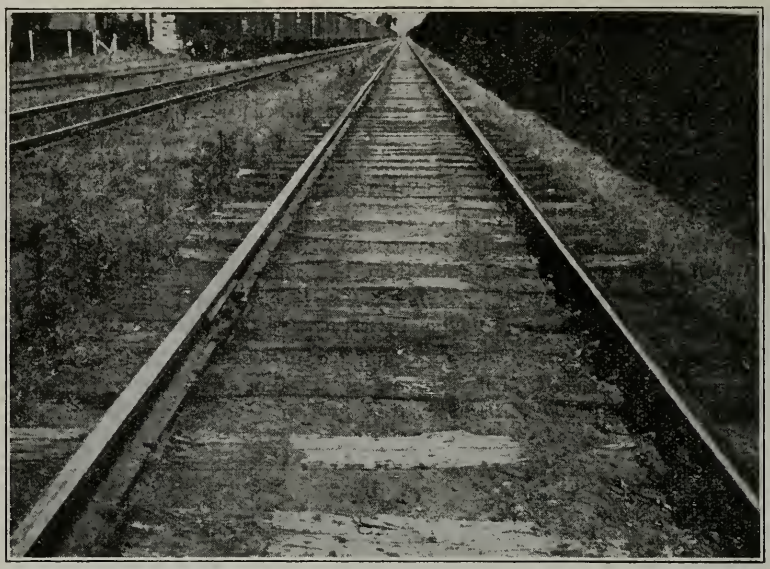

FIG. 4.—A Straight-Away View Showing Creosoted Ties in Track. The Streak Extends as Far as One Can See.

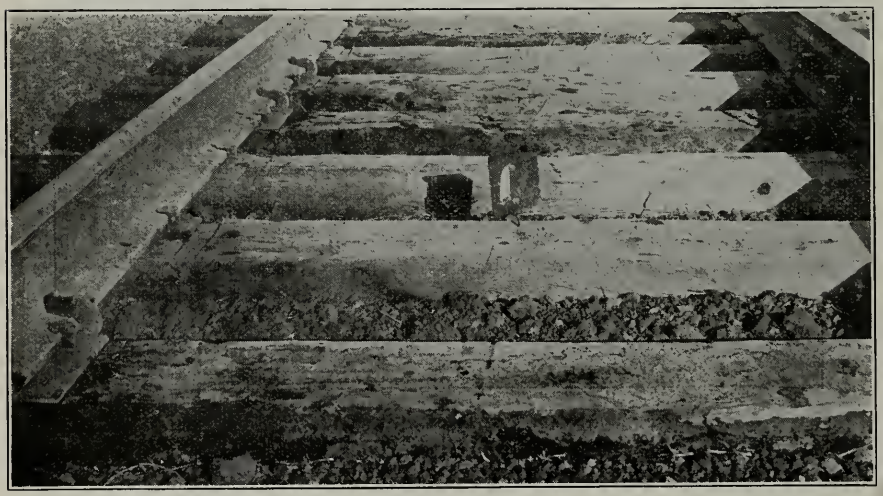

FIG. 5.—Creosoted Hewn Western Pine Inserted 1927. Note Coating Has Been Removed from Surface of Ties.

physical injury has resulted from the softening of the wood and loss of cohesion of the fibers because of hot water and alkali from the blow-off, and the removal of the pitch-like coating from the surface of the tie causing accelerated evaporation of preservative and checking of the tie that would not have taken place had the coating not been removed.

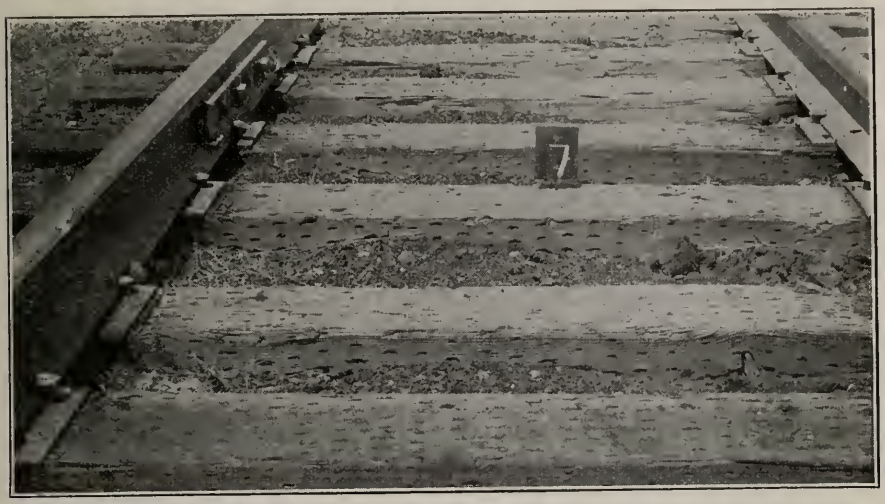

FIG. 6.—Creosoted Douglas Fir Ties Inserted 1923, Followed by Two Pine Ties Inserted in 1925. Note Coating Removed from Center of Ties.

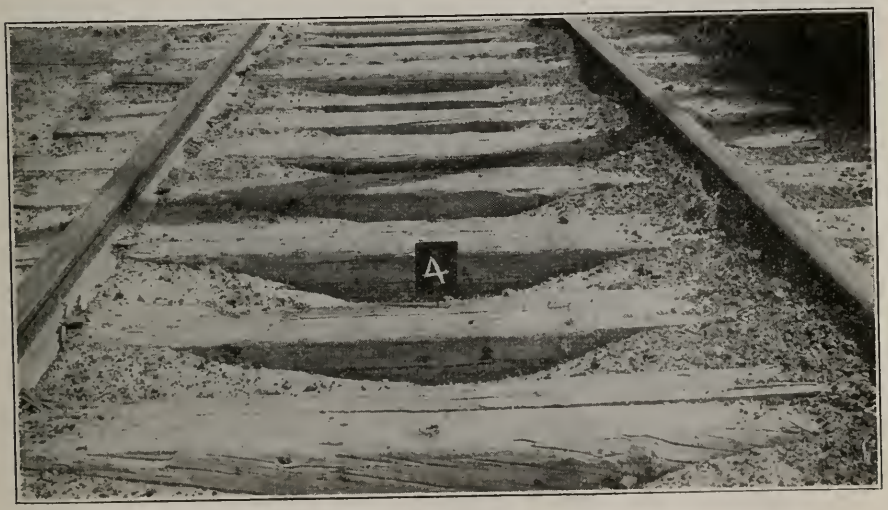

FIG. 9.—Sawn Texas Pine Treated with Creosote Inserted 1929. Note Effect of Blow-Off on Ballast.

The above described tests were carried out by Mr. R. P. Hughes, treating inspector, Atchison, Topeka & Santa Fe. The committee takes this opportunity to express its appreciation for this most interesting contribution.

It is of particular interest to note that results of the tests described above tally closely with previous work along similar lines, thus lending further support to the opinion gained somewhat through earlier findings that, while there may be a slight loss of pre-

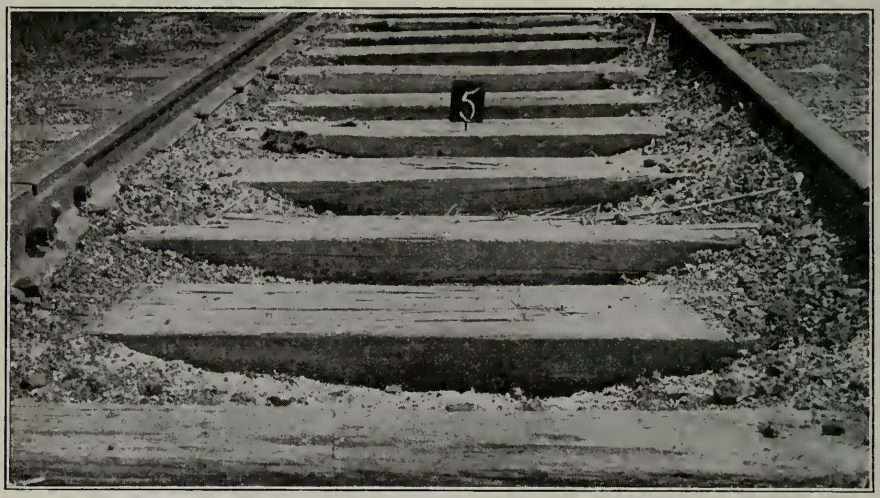

Fig. 8.—Hewn Treated Texas Pine. Note Effect of Blow-Off on Ballast.

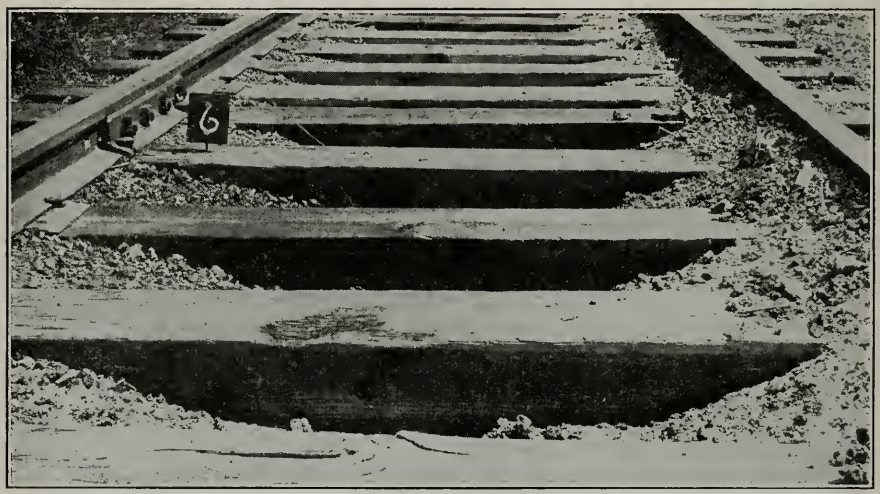

Fig. 9.—Sawn Texas Pine Treated with Creosote Inserted 1929. Note Effect of Blow-Off on Ballast.

servative from continued exposure to the blow-off, the quantity is almost negligible and this particular feature of the operation had little effect on the ultimate service life of ties.

Some of the photographs also disclose the removal of surface coating from mixture treated ties. This results in surface checking, and is particularly objectionable in the more northern territories where alternating freezing and thawing temperatures prevail. Some locomotives are equipped with baffles to retard the direct thrust of the blow. However, further investigation may develop the necessity of applying a heavy asphalt coating to the surface of ties where the center blow-off operation is a regular program.

Note

In accordance with the recommendation of the Committee on Wood Preservation, in the presentation of its report, Appendix G, and the tabulations referred to therein, were withdrawn.

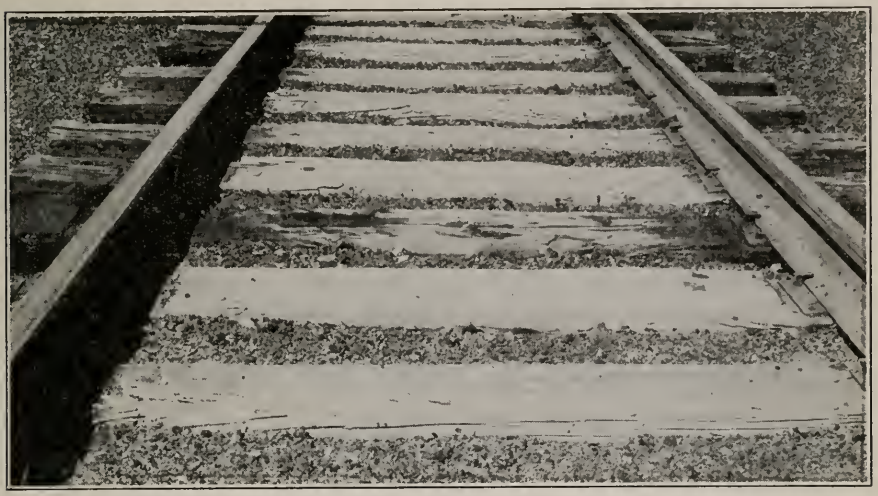

FIG. 10.—Hewn Gum Tie Treated with Mixture of 50 Percent Creosote and 50 Percent Petroleum, Placed in Track 1930. Note Bleached Appearance and Removal of Coating from Surface of Tie.

Notwithstanding surface checking caused by continuous wetting and drying, together with the slight loss of preservative, it is the opinion of the committee that these harmful effects are greatly overshadowed by the economy, convenience, and satisfactory results otherwise obtained from the blow-off operation as now generally practiced. Further, many more years of actual field service tests will be required to definitely determine the ultimate effect on tie service life, particularly as regards such action as may be due strictly to the loss of preservative.

It is the opinion of the committee, that if the blow-off is operated while locomotive is traveling at speed of not less than 15 miles per hour, with the blow-off operated intermittently, that is, open five seconds, then closed for five seconds, and alternated in this manner until the required amount of blow-off is obtained—with locomotive drifting with throttle closed during this operation,—the track damage is much reduced.

This report is offered as information with the recommendation that the subject be discontinued.

Appendix G

(9) PRESENT PRACTICE AS TO PRESERVATIVES USED

M. F. Jaeger, Chairman, Subcommittee; Walter Buehler, H. R. Condon, E. A. Craft, W. R. Goodwin, L. H. Harper, G. R. Hopkins, H. E. Horrocks, Dr. A. L. Kammerer, W. S. King, F. D. Mattos, F. B. Robins, O. C. Steinmayer.

The committee submits a tabulation summarizing reports received from officers directly responsible for or in charge of treatment, indicating the practice as of March 1, 1938, of the railways listed.

This report is submitted as information, with the recommendation that the subject be continued and report made from time to time as may seem desirable.

REPORT OF COMMITTEE 1—ROADWAY AND BALLAST

A. E. Botts, *Chairman,*
F. W. Alexander,
E. J. Bayer,
E. J. Beugler,
F. W. Biltz,
H. F. Brown,
G. H. Burnette,
Paul Chipman,
A. P. Crosley,
L. J. Drumeller,
R. L. Dyke,
Herbert Ensz,
Geo. S. Fanning,
J. J. Gallagher,
J. A. Given,
A. T. Goldbeck,
F. L. Guy,
A. Haertlein,
F. W. Hillman,
A. R. Jones,
R. B. Jones,
O. N. Lackey,
G. E. Ladd,
W. J. Lank,
H. W. Legro,
E. R. Lewis,
P. J. McCarthy,
Paul McKay,
W. S. Moore,
C. P. Nicholson,
J. A. Noble,
M. C. Patton,
G. W. Payne,
J. M. Podmore,
A. D. Kennedy, *Vice-Chairman,*
T. P. Polson,
W. C. Pruett,
C. S. Robinson,
W. A. Roderick,
L. S. Rose,
E. M. Smith,
Wm. C. Swartout,
H. M. Swope,
H. E. Tyrrell,
S. Walker,
G. B. Wall, Jr.,
A. W. White,
C. S. Wicker,
P. H. Winchester,
G. E. Yahn,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Physical properties of earth materials, particularly
   Their effect upon roadbed performance.
   Structural bearing power. Progress in study—no report.
2. Natural waterways, particularly
   Drainage areas, water runoff, and size of openings.
   Progress in study—no report.
3. Culverts, particularly
   Factors determining their location and type (Appendix A). Recommended for publication in the Manual.
   Vitrified clay pipe culverts. Specifications. Progress report.
4. Formation of the roadway, particularly
   Width of roadbed and angle of slopes (Appendix B). Recommended for publication in the Manual.
   Settlement. Shrinkage. Subsidence. Progress in study—no report.
5. Roadway drainage.
   Progress in study—no report.
6. Roadway protection, particularly
   Slope protection. Progress in study—no report.
7. Tunnels, particularly
   Ventilation (Appendix C). Conclusions recommended for publication in the Manual.
8. Fences, particularly
   Fence posts and braces.
   Corrosion-resisting fence wire, collaborating with appropriate subcommittees of Committee A-5 on Corrosion of Iron and Steel, ASTM. Progress in study—no report.
9. Signs, particularly
   Roadway signs required (Appendix D). Recommended for publication in the Manual.
   Close clearance sign. Progress report.

Bulletin 409, February, 1939.

10. Ballast.
    Section design (Appendix E). Recommended for publication in the Manual. Develop relationship of ballast materials between service behavior and results obtained by Los Angeles testing machine. Progress in study—no report.
11. Investigate the use of asphalt in ballast (Appendix F). Progress report.
12. Revision of Manual.
    Progress in study—no report under this assignment, however, certain additions and revisions of the Manual are recommended, as noted above.

THE COMMITTEE ON ROADWAY AND BALLAST,
A. E. BOTTS, *Chairman.*

Appendix A

(3) CULVERTS

Factors Determining Their Location and Type
Vitrified Clay Pipe Culverts, Specifications

Wm. C. Swartout, Chairman, Subcommittee; F. W. Biltz, J. A. Given, Paul McKay, M. C. Patton, E. M. Smith, A. W. White.

The report on this subject was given careful study by the subcommittee last year and was presented to the 1938 Convention as a progress report for information. It begins on page 323 of Vol. 39 of the Proceedings. The subject was continued. Further study indicated the desirability of some revisions in that report which are given in the text following.

A hard and fast line can hardly be drawn between what is and what is not proper material for the Manual. This book is called "Manual of Recommended Practice" and it is the judgment of this committee that this report can be classified as Recommended Practice.

III—CULVERTS

301. LOCATION AND TYPE

1939

A. WATERWAY REQUIRED

Determination of the proper size culvert opening requires knowledge of the drainage area, runoff, data on past performance, such as highwater marks above, at and below the opening, and pertinent formulas, with experience and good judgment in interpreting them. Consideration of the stream both above and below the opening is necessary. The ideal opening is one in which the velocity of the stream above the opening is maintained or somewhat increased through the opening and below to a point where the flow will have no effect on the railway. See page 1–6.7 of the Manual.

B. SPAN REQUIRED

The span of the culvert should be such that the property above will not be injuriously affected at times of maximum runoff, nor a head created which will induce destructive velocities.

In shallow fills the span may have to be increased to provide the predetermined area. For pipe culverts, where practicable, the cover should be a minimum of three feet below the bottom of tie.

For practical reasons, a minimum size pipe culvert should be established, even though run-off computations may show that a size smaller than the minimum might be used. For main line track a minimum diameter of 24 inches is recommended, while for highway crossings and unimportant track, the minimum diameter may be reduced to 18 inches. Pipe structures smaller than these are difficult to clean out and may be of insufficient capacity if freezing occurs.

C. CHARACTER OF HYDRAULIC TRAFFIC (ABRASIVE, CORROSIVE, ETC.)

Except in localities of such special service classifications as mineralized, organic, and salt water, which are relatively small in area as compared with the entire country, corrosion from soil and water is far less important in shortening the life of drainage structures than is the abrasive action of the hydraulic traffic. So far as soil corrosion on the outside of structures is concerned, the extensive soil corrosion tests of the Bureau of Standards, now in progress for more than 12 years, show conclusively that in only about 10 percent of the soils is corrosion from the outside severe; that in about another 10 percent the corrosion is mildly severe, and that in more than 80 percent the soil corrosion is negligible.

Turning to internal corrosion, mine water, especially from coal mines, is particularly difficult to handle as it attacks all commonly used materials except possibly well burnt vitrified clay pipe.

The alkali soils are of two kinds, black alkali and white alkali. White alkali usually contains quantities of sulfates, carbonates or chlorides, which on evaporation of moisture in the soil leaves a white crust on the surface. The black alkali, a sodium carbonate, does not leave the white crust.

The white alkalies, particularly the sulfates, are more severe on concrete than metal. The black alkalies and the chloride salt alkalies, on the other hand, are relatively more severe on metal than on concrete.

Sea water is injurious to all types of drainage materials. The chlorides in the salt water shorten the life of metal structures, while the alternate wetting and drying, and the frost action in cold climates accelerate the deterioration of concrete.

Wherever the service conditions are such as to indicate severe abrasive or corrosive action, the available drainage material that will be least affected should be used, resulting in a structure that will give the lowest cost per year of service.

D. TOPOGRAPHIC CONDITIONS DETERMINING ANGLE, GRADIENT, AND LENGTH OF STRUCTURE

A culvert, being an enclosed channel substituted for an open waterway, is a fixed section of what is possibly an unstable stream that is changing its course, scouring deeper, or filling up. The alinement, gradient and length of the structure should therefore be determined so as to obtain the most economical safe installation.

The best alinement is that which gives the water a straight entrance into the culvert and a direct exit. A stream that is very crooked, or one that is changing its course, may possibly be relocated to make it cross the roadbed at or near a right angle, but the best general principle is to make the alinement of the structure coincide as nearly as possible with that of the stream.

A culvert should usually be given the same general gradient as the stream bed. One of the most common mistakes is to place the invert at the same elevation as the stream bed. The result is that sedimentation reduces the effective area of the opening. It is generally preferable to have the bottom of the culvert two to four inches above the stream bed.

Under new fills where there is a possibility of subsidence of the natural ground thereunder, culverts should be laid or constructed with sufficient camber so that there will be no dips or depressions in the culvert when subsidence has stopped.

The length of a culvert depends upon the shoulder-to-shoulder width of the roadbed, the height of fill, the slope of the embankment, the gradient of the culvert, the skew angle, and whether or not headwalls are to be built. The best method of determining the required length is by the use of a cross-sectional sketch of the embankment and a plan and profile of the water course.

E. FOUNDATION CONDITIONS

Every structure should have the best foundation possible to obtain within the limits of the allowable cost for the structure. But it is not always possible to obtain a satisfactory foundation for some types of structures at a reasonable cost, and it is in these cases that cost comparisons may play an important part in the choice of the type of structure to be used. The heavier a structure is per foot of length, the greater the required bearing power of the soil underneath. In the case of rigid types of structures, cradling or even piling is sometimes necessary. In all cases backfill should be thoroughly tamped and compacted.

F. HEIGHT AND CHARACTER OF EMBANKMENT

A factor that must be considered in the selection of structures is that of transverse forces in fills. These forces are manifested by the tendency of the fill material to move downward and outward, seeking its angle of repose and tending to separate the lengths of pipe culverts and open cracks in masonry. Transverse forces are present in every fill but are likely to be particularly severe on sidehill locations.

G. LOADING, LIVE AND DEAD

Extensive research work on the problem of culvert loading and design has been done. The results of this research are given in the following references:

1. Iowa State Experiment Station, Ames, Iowa
   Bulletin 79, "Experimental Determination of Static and Impact Loads Transmitted to Culverts".
   Bulletin 96, "Theory of External Loads on Closed Conduits".
   Bulletin 112, "The Supporting Strength of Rigid Pipe Culverts".
2. American Railway Engineering Association,
   Vol. 27, page 794, 1926 Proceedings
   Vol. 29, page 527, 1928 Proceedings

   Discussion and analysis of culvert loading and failures as developed by tests carried out under the sponsorship of this committee at various points, including the Farina test under high fills on the then new Edgewood cut-off of the Illinois Central Railroad. These tests embraced both rigid and flexible type culverts.
3. A culvert pipe placed under an embankment derives its ability to support the superimposed load from two sources:

   (a) the strength of the pipe ring or shell to resist external pressures; this may be termed inherent strength, and

   (b) the lateral pressure of the embankment material upon the sides or vertical projection of the pipe, producing stresses in the pipe ring directly opposite to those produced by the vertical load and therefore assisting the pipe in supporting the vertical load.

In a rigid pipe, such as concrete, cast iron, burnt clay, etc., the inherent strength of the pipe is the predominant source of supporting ability. The only lateral pressure that can be safely depended upon to augment the load-carrying capacity of the pipe is the active lateral pressure of the embankment material since the rigid pipes deform but little, if any, under the vertical load and consequently the sides do not move outward enough to develop any appreciable passive resisting pressure in the surrounding embankment material.

In a flexible pipe the stress situation is reversed. The pipe itself has relatively little inherent strength, therefore, a large part of its ability to support the vertical load must be derived from the passive pressures induced or set up as the sides move outward against the surrounding material. The ability of a flexible pipe to deform readily without failure and thus utilize the passive pressures set up on the sides of the pipe is its principal distinguishing structural characteristic and accounts for the fact that such a relatively light-weight pipe of low inherent strength can support high embankments without showing evidence of structural distress.

H. ECONOMICS OF VARIOUS TYPES

Since what is required at any opening is a suitable continuing passageway for the water, any economic study must include (1) interest on the investment, (2) maintenance costs, and (3) provision for an annual payment which will accumulate to a sufficient amount to replace the structure at the end of its useful life (or retire bonds sold to secure funds for the existing structure—the result being the same from an economic study standpoint). The sum of these three charges is the annual cost. The principle involved is long established and widely used. A detailed description will be found on page 1–35 of the Manual.

To arrive at the amount of interest on the investment, the initial cost installed must be determined. The items that go to make up this cost are: Engineering; superintendence; labor; material, tools, equipment, supplies, and transportation and handling thereof, including stores expense; for supporting tracks—sheeting, shoring, pumping, excavation, including channel changes, building the structure, backfilling and restoring the tracks; all the costs from inception to completion.

In preparing cost estimates, different methods of installation should be investigated. Under some conditions, when using pipe, a sizable saving can be made by such methods as tunneling, threading, and jacking.

Having arrived at the cost of the structure ready for service, the first item of annual cost is obtained by multiplying this initial cost by the average interest rate paid on railroad bonds over a period of years.

The second item is that of maintenance, the estimate of which should be based upon actual records of costs of maintenance of similar structures.

The third item, replacement annuity, is dependent upon the sum necessary to be accumulated, the rate of return on sinking funds, and the useful life of the structure. With this information and a table of annuities, the third item in the annual cost formula is easily obtained.

The useful life for structures of various types should be estimated for each major service classification, from records of the company, or from an examination of structures in each service classification that have been in service for at least 5 to 10 years. Much can be learned from a painstaking field inspection of existing structures if all factors affecting the performance of the structures are taken into consideration.

Since cost comparisons are so easily made, and since it is one of the chief functions of a railroad engineer to operate the road, in so far as his sphere of influence extends,

at the lowest true annual cost possible, economic comparisons should be made one of the guides toward the selection of drainage structures.

It is recommended that the above be approved for inclusion in the Manual.

302. VITRIFIED PIPE CULVERTS

A. SPECIFICATIONS

The American Society for Testing Materials has a vitrified clay pipe specification, C 13–35, which was issued as a tentative standard in 1917; adopted in amended form in 1920 and revised and adopted as standard in 1924 and 1935. This specification covers a single class of pipe, namely, that which is generally known as "Double Strength". There is now available on the market a third class known as "Triple Strength" in sizes 15 in., 18 in., 21 in. and 24 in. in diameter.

This latter class of pipe has a crushing strength per linear foot of from 2,000 to 3,000 d, where "d" is the diameter in feet. It will undoubtedly be found much superior, as a railroad culvert pipe, to any burnt clay pipe heretofore used.

Preparation of a specification for it is now being studied jointly by a subcommittee of Committee C–4 of the ASTM and your committee, and it is planned to bring in a specification which will cover both classes as soon as it can be prepared for approval by both organizations. Therefore, for this year, your committee can only report progress.

Appendix B

(4) FORMATION OF THE ROADWAY

Width of Roadbed and Angle of Slopes

Paul Chipman, Chairman, Subcommittee; E. J. Beugler, F. W. Biltz, Herbert Ensz, Albert Haertlein, G. E. Ladd, W. J. Lank, H. E. Tyrrell.

Proposed revision of the Manual, pp. 1–34 and 1–35, under "Recommendations".

The committee recommends the deletion of the material under the heading "A. Width of Roadway at Subgrade" and under the heading "B. Slopes", and the adoption and publication in the Manual of the following:

402. RECOMMENDATIONS

WIDTHS AND SLOPES

1939

Because of the great diversity of conditions, it is not practicable to make specific recommendations as to proper widths and slopes. It is recommended, however, that they be based on consideration of the factors hereinafter enumerated.

Certain factors which govern widths and slopes are general in character and application, while others are of a local and special nature. Obviously, standards should be based on general factors, and modified where unusual conditions exist. Liberal provision should be made for variation in the general factors; but it is not economical to establish a standard width for roadbed which will take care of conditions that, even though of frequent occurrence, prevail over a relatively small part of the line under consideration. It is, therefore, necessary to consider first the determining factors that are of general application; and, second, those which apply to local situations.

A. WIDTHS OF ROADBED

Factors Affecting Standard Widths

Ballast Section

In determining the proper width of roadbed, the ballast section is the primary consideration. Its depth and consequently its width is largely dependent on traffic. Most railroads have two standard roadbed sections, one for principal lines and one for secondary lines; while some have still a third for branch lines.

The ballast section considered for this purpose should be that which is expected to be in use 15 to 25 years after construction. This period would depend on the relative cost of original grading and subsequent widening. It is not economical to anticipate ballast lifts so far in the future that interest on the added cost of original construction would be more than the excess cost of widening under traffic when the need developed. The amount of such excess cost would depend largely on density of traffic.

Erosion and Settlement

An allowance should be made for the rounding and sloughing that results from settlement, erosion, and frost action. This refers to the normal settlement that may be expected at practically all fills, unless thoroughly compacted; and does not include settlement due to subsidence, except for the small amount that results from compression of the natural soil under the weight of embankments and trains. This occurs at nearly all points, even in cuts, although frequently very small in amount, and is quite different from subsidence due to lateral displacement of the underlying material. It also refers to the normal erosion of slopes and rounding of shoulders, which is a universal experience.

The amount of such normal allowance is affected by several factors. It may be less where modern methods of construction have resulted in thorough compaction of embankments, and should be greater where prevailing soils are of a nature particularly susceptible to erosion by water or wind, or where heavy rain storms are frequent.

The factor of settlement does not affect the width of roadbed in cuts, but there is a like tendency to round off the shoulder of the roadway, and erosion from cut ditches must be guarded against. As the function of the roadbed is the same, the majority of railroads find it desirable to use the same width of roadbed between side ditches of cuts as on fills.

To insure adequate support for the ballast, a roadbed shoulder of not less than 18 inches should be maintained outside the toe of the ballast slope. To do this and make allowance for normal erosion and settlement will ordinarily require the standard width of roadbed to be about 5 feet more than the width of base of the ballast section.

Standards in Use

In 1937 a questionnaire as to standard widths and slopes was sent to a number of Class I railroads and replies were received from 31 roads with a total mileage of 132,000 miles. For fills on principal lines, the narrowest standard reported in answer to the questionnaire was 18 feet and the widest 24 feet, the weighted average being 20 feet 6 inches.

The widths reported and approximate percentages of mileage of roads using the various widths are as follows:

Width	*Percent of Mileage*
18 feet	14
Over 18 " and under 20 feet	5
20 "	51
Over 20 " and under 22 feet	8
22 "	6
Over 22 " and under 24 feet	2
24 "	14

For secondary lines, the minimum width was 16 feet and the maximum 22 feet, the weighted average being 19 feet 3 inches. Branch lines had the same range, but with a weighted average of 17 feet 6 inches.

Special or Local Factors Affecting Width

While the function of the roadbed of embankments is similar to that in excavation, the problem of establishing and maintaining it is entirely different. Embankments are artificial and their action is governed by the foundation on which they are placed, by the material of which they are composed and by the method used in their construction.

Earth Fills

Height

High fills not only have more shrinkage; but are more subject to subsidence, on account of their greater weight and the softer nature of the soil that often underlies them. It is customary to add additional height to care for the estimated shrinkage, but at bridge ends such estimates must be conservative and not greatly in excess of the shrinkage that will take place during construction. Unless the fill is so compacted as to minimize shrinkage, it will continue to shrink long after operation begins. A good part of the subsidence will probably take place during construction, but the chances are that some of it will continue. The settlement from these two causes must be made up by successive ballast lifts, with the result that the embankment becomes too narrow to properly support the ballast.

It is, therefore, generally necessary to provide additional width for high fills at bridge ends or at other places where the original grade line should be maintained. Thorough compaction of the fill will minimize the widening required. The modern practice of using trucks for hauling and building earth fills in layers will go far toward making unnecessary certain precautions that have been needed in the past. Still more thorough compaction with a sheep's foot roller is advocated by many.

The higher the fill, the more rain water falls on its slope and the greater the destructive effect of resulting erosion near its base, thus steepening the central part of the slope and reducing the support of the shoulder. Ordinarily, this effect is negligible, but in certain easily eroded soils, it is sufficient to make widening advisable, especially if the region is subject to heavy rain storms. However, protection of the slope by vegetation, by flattening it, or by the use of terraces, may render such widening unnecessary.

Subsidence

Compaction may almost eliminate shrinkage, but has no effect upon subsidence. Where soundings or soil tests show that subsidence may be expected, and the soft underlying material is not to be excavated and replaced, or where subsidence has actually been encountered during construction, a liberal increase in width should be provided, as settlement from that cause is apt to continue, perhaps for many years.

Other Narrowing Causes

Wherever it is necessary to flatten the slopes of fills on account of unstable or saturated materials, or possible erosion of the base of the fill by streams, it is usually also desirable to make some increase in the width, in addition to other protective measures.

Earth Cuts

Ditches

The most important factor affecting the width of cuts is the size of the ditches required. The cut ditches shown on standard plans are the minimum size and depth, and are to be so increased as to make liberal provision for all drainage requirements. These requirements should be reduced where possible by constructing intercepting ditches above the slope on the high side of the cut. It is obviously not economical to widen a cut to carry water that might be kept out of it.

In long cuts, the flow resulting from rainfall on slopes and roadbed will make wider ditches necessary. The size of ditches is affected by the rate of grade, but on steep grades, erosion of the roadbed must be guarded against by increasing its width or by protecting it with riprap or paving, or both.

Advantages of Wide Cuts

Within reasonable limits any additional width of large cuts has some value. It gives room for ditches of ample size and of such depth as to provide good drainage for the roadbed and shut off ground water from reaching it. It provides lodgment for material washed down the slope of the cut and reduces the frequency of cleaning ditches.

In country subject to heavy snow fall, extra width of cuts is a distinct advantage, reducing the depth of drifts and affording a place to deposit snow removed from the track.

These considerations should be borne in mind in establishing the grade line on new construction. Failure to do so has often resulted in heavy expenditures later, either for maintenance or widening.

B. SLOPES

Earth

The angle of repose of the material is the governing factor in determining slopes. For most earth materials, this is in the neighborhood of 1½ horizontal to 1 vertical, and this slope is generally standard for both fills and cuts on railroads, to be departed from to meet special conditions.

Freshly made fills will usually stand at a slightly steeper slope than 1½ to 1. Freshly made cuts will usually stand for a long time at much steeper slopes, but in general, frost action and erosion will in the course of years bring them to a slope approaching that of the same material in fills.

Effect of Erosion and Weathering

Assuming that the slope is not greater than the angle of repose of material when either wet or dry, the general effect of weathering is to round off and flatten the slope at its top, while the deposit of eroded material produces a similar but much greater effect at its toe.

A slope of 2 horizontal to 1 vertical is approximately one-third longer than a slope of 1½ horizontal to 1 vertical and it receives one-third more rain fall. The result is

that the deposit at its toe may be as great or greater than for a steeper slope. Where cuts are widened, a resting place is provided for the greater portion of this material.

Slides

Where slides are encountered in cuts, either during construction or afterward, it is necessary to excavate the material until equilibrium is restored, thus automatically flattening the slope.

When a fill is subject to saturation on account of water standing against its slope, it may be stabilized either by flattening the slope below the water line, by terracing, or by placing riprap in sufficient amount to overcome the outward pressure of the saturated soil in the fill. Such use of riprap is generally more economical than flattening the slope and is preferred by most railroads. It should be carried well above the water line as protection against erosion by waves or ice.

Widening Cuts Versus Flattening Slopes

Where more material is to be taken from cuts than is required by the standard section and drainage requirements, in order to secure material for fills, the relative merit of widening cuts and flattening their slopes is worthy of consideration. Flattening a slope increases its length and consequently the erosion and wash due to rain fall. For deep cuts it may make the purchase of additional right-of-way necessary. There is little advantage in using slopes that are much flatter than the angle of repose of the material; whereas the benefits from widening cuts are considerable.

An exception is the case of shallow cuts in regions of heavy snow fall, in which very flat slopes of, say 4 horizontal to 1 vertical, prevent the formation of drifts, and are desirable where the material can be used to advantage. The material required to reduce slopes from 1½ to 1, to 2 to 1 will widen the cut one-half its depth, and the latter will in the great majority of cases result in more benefit.

The desideratum on most slopes is to secure a growth of vegetation that will bind the surface soil and prevent erosion. Where the angle of repose of loose material is not exceeded, vegetation will gain a footing if the soil is rich enough to support it. If not, a flatter slope will not help very much.

Terracing

Few railroads have used terracing to any considerable extent, and among these there is wide diversity in practice as to width and height of terraces. Nearly all of such work has been done on fills. One western road uses a width of 6 feet if the fill is over 25 feet high, with an additional terrace 12 feet wide if over 50 feet.

In some cases it may be desirable to terrace deep cuts, possibly providing them with paved gutters with separate outfall ditches at the ends of the cut. It is evident that to be effective, terracing must be carefully done. If not built accurately to grade, the result will be an overflow at low points, which may be more destructive than if no terracing were done.

Rock

For rock cuts no definite rule can be laid down, owing to the diversity of the materials which come under that classification. Each case should be considered on its own merits and handled accordingly. Slopes of ½ horizontal to 1 vertical for loose rock and ¼ horizontal to 1 vertical for solid rock are commonly specified, but may be departed from as circumstances require. Some solid rock is safe when perpendicular, but most varieties should have some slope, especially if the cut is deep.

When rock is overlaid by earth, a berm should be left between the top of the rock slope and the toe of the earth slope, the width of which should not be less than 5 feet and should be more if the depth of earth exceeds 10 feet.

Conclusions

1. The standard width of roadbed should be determined by conditions that are generally prevalent. The considerations which govern the standard width of roadbed are the width of the ballast section and provision for normal settlement and erosion.

2. The principal factors which require more than standard width are: For cuts, drainage requirements; for fills, height and settlement.

3. The standard slope for earth cuts and fills should be slightly less than the angle of repose of the prevailing materials when loose. A slope of 1½ horizontal to 1 vertical will usually comply with this condition.

4. The principal factor which may require flattening of slopes is the instability of material; but flattening the slopes of high fills and deep cuts involves much additional grading, and the possibility of other cures, such as draining slopes of cuts and riprapping slopes of fills, should be explored.

5. Terracing may be used to advantage in certain deep cuts and high fills, if carefully done; but in general, it is not necessary.

6. Each cut and fill should be the subject of careful study to determine whether or not surrounding conditions require a departure from the standard, and if so, to what extent and in what way.

Appendix C

(7) TUNNELS

F. W. Alexander, Chairman, Subcommittee; H. F. Brown, Geo. S. Fanning, F. W. Hillman, E. R. Lewis, W. S. Moore, G. B. Wall, Jr.

703. VENTILATION

The committee reviewed the material already in the Proceedings and Manual, also located and reviewed, as far as possible, all published articles on tunnel ventilation. Many of the articles reviewed dealt with underground railways or vehicular tunnels, mines, etc., so they are not pertinent to the ordinary railway tunnel.

A questionnaire was sent to 11 of the larger railway systems. This selection of railways was made to cover all the longest tunnels in Canada and the United States and the major number of all tunnels with a length of 2,000 ft. and over. These questionnaires received such a good reception that the committee can report complete replies from all roads addressed.

From the various published articles reviewed, a selection was made of those having a direct bearing on the committee's assignment, and a few others were selected that appeared to be of especial interest, and these have been assembled in a bibliography, which is presented as Exhibit I. Attention is directed to the reference at the end of this bibliography, to the Index of the AREA Proceedings, 1900–1915, for valuable information on the subject.

The information on the folded inserts is tabulated from answers to questionnaire. The column headed "Rate of Grade Through Tunnel" only shows major grades except in cases where there is a decided summit, in which cases the + and — grades are shown.

One question read—"What is your opinion as to the minimum length of tunnel requiring artificial ventilation?"

Replies to this are not tabulated because of the large amount of space they would occupy. The replies, however, were in general agreement and are summarized below:

1. Ordinarily not less than 2,500 ft. Depends on local conditions.
2. Alinement and area of tunnel section, as this has an influence on heat, as well as smoke conditions.
3. Lining, or lack of same, also wetness in the tunnel, as these affect the movement of air currents and speed of clearing.
4. Grade of approach and through the tunnel compared to ruling grades of the subdivision, which will, in turn, affect the speed of trains. This governs time, and to a considerable extent smoke conditions within the tunnel.
5. Prevailing winds and situation as to general atmospheric conditions.
6. Interval between trains.

It will be noted from the folded inserts that there are many steam operated tunnels over 4,000 ft. in length without artificial ventilation, in which conditions are reported as being satisfactory. The committee feels that it would consume too much time and space to make a complete analysis of the whole table, but calls attention to some outstanding examples of single-track tunnels, carrying traffic in both directions, without artificial ventilation. The maximum length in this class is 6,994 ft. This is a single track tunnel with a light train movement. There is a tunnel 7,340 ft. long without artificial ventilation but in that case electric motors are used to pull trains up the grade, which is 0.8 percent. There is also one 7,369 ft. long where ventilation is reported "not bad".

Another example is a tunnel 6,206.7 ft. long with a minimum inside area of 282 sq. ft., two trains an hour at peak period and an average of six trains for 24 hours. This tunnel has a decided summit. Nevertheless, the ventilation is reported as satisfactory. The same road reports a tunnel 3,610.3 ft. long, minimum area the same, 3 trains per hour at the peak period and an average of 19 trains in 24 hours. This latter tunnel has a summit. The grade in one direction is very heavy. The ventilation in this particular tunnel is reported as unsatisfactory.

The difference in ventilation in these cases seems to be explained by the difference in rate of grade through individual tunnels as compared with rate of ruling grade on the subdivision. In the former tunnel the maximum grade is 0.273 percent, with a ruling grade on subdivision of 2.6 percent. In the latter, the grade is 2.2 percent, the same as the ruling grade on the subdivision.

Ventilating fans may be located at either the upper or lower end of the tunnel. In cases where ventilating fans are at the lower end, trains are generally held to a speed that keeps them behind the smoke, and in at least one instance of this type of installation, due to the short time in the tunnel, fans are not operated for passenger trains. If fans are at the lower end and trains are kept behind the smoke, a considerable increase in fan capacity and power is necessary, or train speed must be reduced. These factors are, of course, qualified by the length of the tunnel. Local authorities may be the governing feature in the fan location; for instance, in one case a city would not allow smoke to be discharged at the lower end.

The arrangement of ventilating fans at the Moffatt tunnel on the Denver & Salt Lake Railway is the only one of its kind on record. By a special arrangement of dampers and door at the fan end, air can be either forced into or exhausted from the tunnel.

The Vancouver tunnel of the Canadian Pacific Railway is another exception, with respect to the general type of operating equipment. Synchronous motors run continu-

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LIST OF RAILROAD TUNNELS 2000 FT. LONG OR OVER NOT VENTILATED.

4 Sheets

LOCATION OF TUNNEL	SINGLE OR DOUBLE TK	RATE OF GRADE	LENGTH OF TUNNEL	LENGTH ON CURVE	MAXIMUM CURVATURE	MAXIMUM CROSS SEC IN SQ. FT	MINIMUM CROSS SEC IN SQ. FT	TYPE OF TUNNEL LINING	TRAINS PER HOUR AT PEAK	TRAINS PER 24 HOURS	PERCENTAGE TRAINS MORE THAN ONE ENG	TYPE OF FUEL	TIME IN MIN FOR TUNNEL TO CLEAR OF SMOKE	IS PRESENT NATURAL VENT. SATISFACTORY	RULING GRADE OF SUBDIV.	REMARKS & SUGGESTIONS
BALTIMORE & OHIO RLY.																
Fairmount Park, Phila, Penn	2	1.28%	2303'	699'	8°	513	450		6	74	20%	coal			1.28%	
Howard St. Baltimore, Md.	2	0.8%	7340'	450'	8°	550	476		8	98	10%	coal			1.19%	Trains are handled upgrade thru' this tunnel with electric motors.
Stuart, Magnolia, W. Va.	2	0.10%	3355'	386'	2°30'	687	687		4	37	25%	coal			0.79%	
Knobley, Knobley, W. Va	2	0.3%	4160'	400'	2°	653	653		1	3	5%	coal			0.79%	
Kingwood (new) Tunnelton, W. Va.	2	0.4%	4202'	180'	9°	718	718		2	13	75%	coal			2.2%	
Kingwood (old) Tunnelton, W. Va	1	1.0%	4138'	248'	9°	455	370		2	12	nil	coal			2.2%	
Lane, Pleasant Creek, W. Va.	1	1.0%	2346'	nil		379	379		1	7	40%	coal			1.0%	
#6, West Union, W. Va.	1	0.86%	2297'	15'	6°	270	270		3	18	25%	coal			1.13%	
Board Tree, Littleton, W. Va	1	1.0%	2400'	54'	9°	283	283		1	5	nil	coal			1.47%	
Mt Airy, Mt Airy, Md.	2	0.85%	2758'	982'	1°15'	623	623		2	12	75%	coal			1.19%	
Schenley, Pittsburg, Penn.	2	0.64%	2872'	490'	3°	467	467		5	32	30%	coal			1.38%	
Simson, Horatio, Penn.	1	0.47%	2324'	nil		310	310		3	14	50%	coal			1.0%	
Little Otter, Pembroke, W. Va.	1	0.41%	2360'	nil		310	310		1	4	50%	coal			1.55%	
CANADIAN PACIFIC RLY.																
Bulldog, Tunnel, B.C.	1	1.1% WB	2931'	362'	10°	300	275	Partly timber	2	5	20%	coal	20 to 30	Yes	2.2%	Shorter time is for eastbound trains on downgrade. Only short portions lined at portals.
Mile 0.96 to 1.46, Quebec, Que.	1	0.8%	5288'	73'	12°	350	350	concrete	3	variable	20%	coal	10 to 40	Yes	0.5%	Time of clearing depends on direction of wind. If movements more frequent would require fans
Mile 131.1, Cathedral, B.C.	1	2.01% to 1.62%	2922'	2322	10°	460	356	concrete & timber	1½	24	33%	coal & oil	30 to 90	Yes	2.2%	Clearing time depends on direction of wind. About 70% oil burners, 30% coal burners. Major portion of lining is timber
Mile 128.8, Yoho, B.C.	1	1.66%	3255'	3209'	10°	460	356	concrete & timber	1½	24	33%	coal & oil	30 to 90	Yes	2.2%	In addition to 0.4 compensation, grade in tunnels reduced 0.2% account wet rail.

September 12, 1938.

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LIST OF RAILROAD TUNNELS 2000 FT. LONG OR OVER NOT VENTILATED.

4 Sheets

LOCATION OF TUNNEL	SINGLE OR DOUBLE TR	RATE OF GRADE	LENGTH OF TUNNEL	LENGTH ON CURVE	MAXIMUM CURVATURE	MAXIMUM CROSS SEC IN SQ FT	MINIMUM CROSS SEC IN SQ FT	TYPE OF TUNNEL LINING	TRAINS PER HOUR AT PEAK	TRAINS PER 24 HOURS	PERCENTAGE TRAINS MORE THAN ONE ENG	TYPE OF FUEL	TIME IN MIN FOR TUNNEL TO CLEAR OF SMOKE	IS PRESENT NATURAL VENT. SATISFACTORY	RULING GRADE OF SUBDIV.	REMARKS & SUGGESTIONS
CHESAPEAKE & OHIO RLY.																
Blue Ridge, Afton, Va.	1	1.3%	4263'	18'	10°28'	239	200	brick & natural rock	3	16		coal	EB 6 WB 16	Yes	1.35%	1474' brick lined, 2789' natural rock.
Lewis, E.B. (new) Jerry's Run, Va	1	1.13%	3055'	nil		379	379	concrete	3	16		coal	0	Yes	0.83%	East bound Track.
Seng Creek, Tunnel Siding, W.Va	1	+1% −1%	3959'	472'	6°30'	239	239	concrete	2	10		coal	very quickly	Yes	2.5%	When weather conditions are unfavorable, takes longer to clear.
Alleghany, E.B. (old) Alleghany, Va	1	0.53%	4743'	100'	3°	458	387	brick & concrete	3	18		coal	73	Yes	0.83%	2261' brick lined, 2482' concrete lined. Eastbound track
Alleghany, W.B. (new) Alleghany, Va.	1	0.53%	4751'	nil		376	376	concrete	3	18		coal	5	Yes	0.83%	Westbound track
Big Bend, W.B. (old) Hilldale, W Va.	1	−0.42% +0.27%	6500'	nil		239	239	brick & concrete	3	16		coal	12	Yes	0.66%	6477' brick lined, 23' concrete lined. Westbound track
Big Bend, E.B. (new) Hilldale, W Va.	1	0.15%	6168'	nil		379	379	concrete	3	16		coal	8	Yes	0.66%	Eastbound track
GREAT NORTHERN RLY.																
Boulder, #6, Boulder, Mont.	1	1.3%	6145'	150'	0°30'	275	275	brick & concrete	0.167	4	nil	coal & oil	15 to 50	Yes	2.2%	Clearing time varied by weather conditions. Conditions satisfactory for present business
91, Rimrock, Mont.	1	0.6%	2517'	337'	3°30'			timber	0.167	4	nil	coal	10 to 20	Yes	1.0%	Same remarks as above. Partly lined only.
#17, Seattle, Wash.	2	0.2%	5141.5'	1806.2'	4°	737	737	concrete	8	24	nil	oil & coal	10 to 20		0.4%	Clearing time depends on weather conditions. 85% oil burners, 15% coal burners
#16, Everett, Wash.	1	0.5%	2440'	nil		340	324	concrete	2	12	nil	oil	variable	Yes	2.2%	Ventilation not satisfactory at east end of tunnel where there are overhead bridges.
#15, Berne-Scenic, Wash.	1	1.562%	41,152'	nil		325	325	concrete				electric			2.2%	
#13, Chumstick, Wash.	1	1.5%	2601'	nil				concrete				electric			2.2%	
#14, Winton, Wash.	1	0.85%	4059'4	nil		325	325	concrete				electric			2.2%	
ILLINOIS CENTRAL RLY.																
#2 Reevesville, Ill.	1	0.0	6994'	200	10°30'		420	concrete	3	24	2%	coal	30	Yes	0.3%	Clearing time based on clear weather conditions
#3 Reevesville, Ill.	1	0.186%	2625'	nil			360	concrete	3	24	2%	coal	30	Yes	0.3%	Same remark as above.

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LIST OF RAILROAD TUNNELS 2000 FT. LONG OR OVER NOT VENTILATED.

4 Sheets

LOCATION OF TUNNEL	SINGLE OR DOUBLE TK	RATE OF GRADE	LENGTH OF TUNNEL	LENGTH ON CURVE	MAXIMUM CURVATURE	MAXIMUM CROSS SEC IN SQ. FT	MINIMUM CROSS SEC IN SQ. FT	TYPE OF TUNNEL LINING	TRAINS PER HOUR AT PEAK	TRAINS PER 24 HOURS	PERCENTAGE TRAINS MOVE THAN ONE WAY	TYPE OF FUEL	TIME IN MIN FOR TUNNEL TO CLEAR OF SMOKE	IS PRESENT NATURAL VENT. SATISFACTORY	RULING GRADE OF SUBDIV.	REMARKS & SUGGESTIONS
NORTHERN PACIFIC RLY.																
Bozeman Pass, Muir, Mont.	1	1.2%	3652'	40°	Spiral to 5°	292	275	brick & concrete	2	14	100%	coal		Yes	1.9%	Concrete lining, partly precast blocks.
Nelson-Bennett, Tacoma, Wash.	2	0.30%	4391'	2949'	1° & 3°	587	577	concrete	3	29	nil	coal & oil		Yes	1.12%	
NORFOLK & WESTERN RLY.																
Summit, Bandy, Va.	1	0.32%	4773'	nil		350	350	concrete				coal			0.57% comp. N.B. 1.50% " S.B.	
Staggerweed, Wharncliffe, W.Va.	1	0.30%	4027'	nil		432	432	concrete				coal			0.9% comp. N.B. 1.2% " S.B.	
Raitt, Hurley, Va.	1	0.30%	3766'	186'	spiral	477	432	concrete				coal			1.854% Comp. S.B. 1.72% Comp. N.B.	
#1, Big Sandy Line, Kemit, W.Va.	1 & gauntlet		2626'	120'		357	321	concrete				coal			0.30% W.B. 0.66% E.B.	
SOUTHERN PACIFIC RLY.																
#28, E.B. Applegate, Cal.	1	+1.54%	3208.86	25.73	Taper	360	360	concrete & timber	3	13	75%	oil	20 to 40	Yes	2.5%	
#21, E.B. Norden, Cal.	1	-1.4%	10325.66	nil		360	360	concrete & rock	3	13	nil	oil	10	Yes	2.5%	Downgrade on this track.
#1, Dorris-Calor, Cal.	1	+0.15% -0.2625%	2070'	1696.2	2°45'	340	326	concrete & timber	1	16	5%	oil	20	Yes	1%	134' concrete lined, 1936' timber lined.
#1, Wright, Cal.	1	+0.2704% -0.2737%	6206.7	nil		371	282	concrete brick timber	2	6	17%	oil	90	Yes	2.6%	Decided summit in this tunnel.
#2, Laurel, Cal.	1	+0.282% -0.294%	5791.7	96.72	Taper	371	282	concrete & timber	2	6	17%	oil	90	Yes	2.6%	Same remark as above.
#3, San Francisco, Cal.	2	+0.10% -0.254%	2364'	nil		968	968	brick & concrete	15	115	less than 1%	oil	15	Yes	0.4%	
#4, Bayshore, Cal.	2	0.10%	3547'	261.9	1°	968	902	brick & concrete	15	115	less than 1%	oil	15	Yes	0.4%	
#6, Cuesta, Cal.	1	+0.2% -2.2%	3610.33	44.55	Taper	371	282	concrete & timber	3	19	70%	oil	up to 180	No	2.2%	Summit in this tunnel Ventilating shaft at apex and blowers suggested.
#25, Tunnel, Cal.	1	+1.995% -0.70%	6976'	nil		324.5	324.5	concrete	2	17	48%	oil	30 to 120	Not bad	W.B. 2.12% E.B. 2.225%	
#26, Hasson, Cal.	1	1%	7368.99	nil		311.73	295.25	concrete	4	22	18%	oil	30 to 120	Not bad	E.B. 1.021% W.B. 1.00%	

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LIST OF RAILROAD TUNNELS 2000 FT. LONG OR OVER NOT VENTILATED.

4 Sheets

LOCATION OF TUNNEL	SINGLE OR DOUBLE TR	RATE OF GRADE	LENGTH OF TUNNEL	LENGTH ON CURVE	MAXIMUM CURVATURE	MAXIMUM CROSS SEC IN SQ FT	MINIMUM CROSS SEC IN SQ FT	TYPE OF TUNNEL LINING	TRAINS PER HOUR AT PEAK	TRAINS PER 24 HOURS	PERCENTAGE TRAINS MORE THAN ONE ENG	TYPE OF FUEL	TIME IN MIN FOR TUNNEL TO CLEAR OF SMOKE	IS PRESENT NATURAL VENT. SATISFACTORY	RULING GRADE OF SUBDIV.	REMARKS & SUGGESTIONS
SOUTHERN PACIFIC RLY. (cont'd)																
#13, White Point, Siskiyou, Ore.	1	2%	3107.70	nil		252	252	timber	2/3	8	50%	oil	30 to 50	Yes	3.3%	
#3, Cascade Summit, Ore.	1	1.6%	3654.61	802.36	Tapers to 5°	386.41	363.31	concrete & timber	2	21	33⅓%	oil	45	Not entirely	1.8%	
#7, Cruzatte, Ore.	1	1.74%	3164'	2076.7	6° to 8°	386.41	349.0	Concrete & timber	2	21	33⅓%	oil	45	Not entirely	1.8%	
#14, Frazier, Ore.	1	1.75%	2121.43	682'	6°	386.41	333.8	Concrete & timber	2	21	33⅓%	oil	30	Yes	1.8%	
#16, Fields, Ore.	1	1.45%	2213.41	2213.41	4°50'	386.41	363.31	concrete & timber	2	21	33⅓%	oil	30	Yes	1.8%	
#8, Wolf Creek, Ore.	1	1.5%	2811.0	214.5	Spiral		229.0	Concrete timber unlined	1	4	nil	oil	45	Yes	2.05%	
#9, Hugo, Ore	1	1.2%	2104.8	76.62	Spiral	275.7	244.3	concrete & timber	1	4	nil	oil	20	Yes	2.10%	
#13, Vaughn, Ore.	1	+0.6% -0.6%	2488.66	755.66	8°		316	concrete & timber	1	4	nil	oil	30	Yes	0.6%	
#15, Siboco, Ore.	1	0.40%	2132.91	141.58	Taper		318	concrete & timber	1	4	nil	oil	30	Yes	0.4%	
#19, Tharp, Ore	1	-0.262% +0.40%	4182.91	225.48	6°	332.8	318.45	concrete & timber	1	4	nil	oil	45	Yes	0.40%	
#3, Ryndon, Nev.	1	0.00% 0.40%	476.56	nil		363	315	concrete & timber	3	24	nil	oil	15	Yes	1.5%	
#4, Ryndon, Nev.	1	0.00% 0.40%	3926.30	nil		363	315	concrete & timber	3	24	nil	oil	15	Yes	1.5%	
SOUTHERN RLY. SYSTEM																
#24, Nemo, Tenn.	1	0.5%	2031'	2031'	4°	255	240	stone & brick	4	44	nil	coal	5 to 15	Fairly	1.14%	Shorter time is for southbound trains on downgrade.
Burton, French Lick, Ind.	1	0.53%	2217'	100'	4°30'	310	300	concrete	1	4	nil	coal	15	Yes	0.78%	
UNION PACIFIC RLY.																
Peninsula, Peninsula Jct. Ore	1	0.36% 0.50%	5436'	nil		332.5		concrete	4	30		oil & coal	10	Yes		Very few trains with more than one engine
Aspen, Aspen, Wy.	1	0.40%	5941'	nil		316	237	concrete	4	40	35%	coal		Yes	0.8% Approach to East Portal; 0.4% " " West " .	Min. area extends for 750' only.
Namorf, Namorf, Ore	1	0.5%	2537.5	1117.5	4°	385		timber		4	nil	coal		Yes		

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LIST OF RAILROAD TUNNELS MECHANICALLY VENTILATED.

1 sheet

LOCATION OF TUNNEL	SINGLE OR DOUBLE TK.	DATE OF FAN INSTALLATION	RATE OF GRADE	POWER TO DRIVE FANS	LOCATION OF FANS	CAN AIR CURRENT BE REVERSED	LENGTH OF TUNNEL	LENGTH OR CURVE	MAXIMUM CURVATURE	MAXIMUM CLEAR SEC. IN SQ. FT.	MINIMUM CLEAR SEC. IN SQ. FT	TYPE OF LINING	CU. FT. OF AIR DELIVERED PER MIN. THROUGH	TRAINS PER HOUR AT PEAK	AVERAGE TRAINS PER 24 HRS.	PERCENTAGE TRAINS BORE TRAIN ONE ENG.	TYPE OF FUEL	TIME IN MIN. FOR TUNNEL TO CLEAR OF SMOKE	IS PRESENT TYPE VENTILATION SATISFACTORY	RULING GRADE OF SUBDIV.	REMARKS & SUGGESTIONS
BALTIMORE & OHIO RLY.																					
#1 Clarksburg W.Va.	1	1922	0.66%	electric	lower	no	2710'	50'	6°	350	268		405,000	3	21	10%	coal	3	Yes	1.02%	Distant control Agent operates fans.
#21 Eaton W.Va.	1	1918	1.10%	steam	lower	no	2021'	231'	5°30'	231	231		300,000	2	18	25%	coal	3	Yes	1.13%	
CANADIAN PACIFIC RLY.																					
Connaught, Glacier, B.C.	2	1916	0.95%	oil	upper	no	26,517.8	518'	Spir. to 4°	540	525	concrete	500,000	1.1	28	30%	oil	15 to 35	Yes	2.2%	Time for clearing tunnel depends on direction of winds and other atmospheric conditions.
Vancouver B.C.	1	1932	0.1% to 0.233%	electric	lower	no	4579'	2118'	12°30'	388	332	concrete	290,000	3	48		coal/soil	6 to 10	Yes	Yard trackage adjusts	Fans controlled automatically by train approach on track circuits.
CHESAPEAKE & OHIO RLY.																					
Lewis, W.B. (old) Jerry's Run, Va	1	1914	1.14%	electric	lower	no	4077'	289'	2°55'	264	264	concrete	150,000	2	16		coal		Yes	0.83%	Remote control of fans. Freights stay behind smoke. Fans not run for pass. trains.
DENVER & SALT LAKE CITY																					
Moffat, East Portal, Col.	1	1928	0.3% E.B. 0.9% W.B.	electric	lower	yes	32,798'	nil		442 to 570	410	concrete gunite	300,000	1	18	60%	coal	20 to 40	Yes	2.0%	Pushers cut off at apex of tunnel.
NORTHERN PACIFIC RLY.																					
Mullan, Skyline, Mont.	1	1914	2%	steam	lower	no	3875'	40'	Spir. to 5°30'	275	255	concrete brick	550,000	2	3	100%	coal	10	Yes	2.2%	
Stampede, Martin, Wash.	1	1914	+0.20% -0.74%	electric	lower		9834'	90'	Spir. to 8°	292	274	concrete brick	540,000	5	12	91.7%	coal	6 to 7	Yes	2.2%	
NORFOLK & WESTERN RLY.																					
Elkhorn or Coaldale W.Va.	1	1915	1.4%	electric	lower	no	2994'	821'	2°	244	244	brick	400,000	10	70	27%	coal electric	20	Yes	1.2% W.B. 2.0% E.B.	Distant control. Telegraph operator starts fans.
Pepper or Horse Shoe Va.	1	1914	0.18%	electric	upper	no	3307'	nil		288	283	concrete	270,000	2½	30	1½%	coal	6 to 10	Yes	1% Comp E.B. 1.4% not comp W.B.	Same remarks as above

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LIST OF RAILROAD TUNNELS AIR SHAFT VENTILATED.

LOCATION OF TUNNEL	SINGLE OR DOUBLE TR.	RATE OF GRADE	NUMBER OF SHAFTS	SIZE INSIDE CROSS SEC.	LENGTH OF TUNNEL	LENGTH OF CURVE	MAXIMUM CURVATURE	MAXIMUM GROSS SEC IN SQ. FT.	MINIMUM GROSS SEC IN SQ FT	TYPE OF TUNNEL LINING	TRAINS PER HOUR AT PEAK	AVERAGE TRAINS PER 24 HOURS	PERCENTAGE TRAINS HORE THAN ONE ENG.	TYPE FUEL USED	TIME IN MIN FOR TUNNEL TO CLEAR OF SMOKE	IS PRESENT VENTILATION SATISFACTORY	RULING GRADE OF SUBDIV.	REMARKS & SUGGESTIONS
BALTIMORE & OHIO RLY																		
Sand Patch, Sand Patch, Penn	2	0.5%	2	525&325	4476'	nil		718	718	brick	7	40	50%	coal	20	No	1.6%	Smoke would clear from tunnel faster if shafts were closed up so as to let draft from trains go through undisturbed.
#3 Short Line, Rinehart, W Va	1	0.53%	1	63	3191'	419'	8°	276	276	brick	3	11	50%	coal	15	No	0.35%	Same remark as above.
SOUTHERN RLY SYSTEM																		
#2, King's Mountain, Ken.	1	1%	2	98	3984'	249'	Spirals of 5° & 6°	245	235	stone & brick	4	44	nil	coal	10 to 25	Fairly	1.14%	Ventilation would be improved by use of fans.
#15, Robbins, Tenn	1	1.14%	1	98	2533'	295'	6°	248	238	brick	4	44	nil	coal	5 to 15	Fairly	1.14%	Same remark as above.
Lookout Mtn, Chattanooga, Tenn	2	042%	1	35	3537'	1615'	3°	557	520	brick	4	24	nil	coal	7	Yes.	1.0%	
#1, Duncan, Ind	1	1.3%	2	76&154	4311'	968'	4°	240	225	60' concrete	3	22	40%	coal	30	No.	Descending 2.9% on E approach.	Ventilation would be improved by use of fans

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ously. Fans are automatically started and stopped by a magnetic clutch operated through a track circuit by approaching and departing trains. There are other tunnels with electrically operated fans having distant control, being operated from signal towers or by operators at stations.

In the table of tunnels ventilated by shafts, it will be noticed there is a considerable difference in results. Ventilation is shown as working satisfactorily on some, while at others, it is said that ventilation would be improved if the shafts were closed. The tunnels with shaft ventilation that are reported as satisfactory are all comparatively short, so the probability is that conditions in these would have been satisfactory even if there were no shafts. Shaft ventilation has practically disappeared from modern practice.

Conclusions

1. Artificial ventilation for tunnels 2,500 feet or less in length is unnecessary.
2. For tunnels over 2,500 feet in length, study to determine the proper method of ventilation should be made, giving due consideration to operating and other local conditions.
3. Shaft ventilation is of limited benefit.
4. Where electricity is available, it is the most economical type of power for operating a mechanical ventilating plant.

Recommendations

The committee recommends:—

1. That conclusions 1 to 4 inclusive be approved and printed in the Manual preceding the matter under Ventilation.
2. That the remainder of the report be received as information and the subject discontinued.

Exhibit I

BIBLIOGRAPHY OF RAILWAY TUNNEL VENTILATION

Arlberg—Length 6.4 miles. Arlberg RR.

(1) Engineering News, Mar. 18, 1897, p. 175.
(2) Railroad Gazette, Apr. 2, 1897, p. 240.
(3) Railroad Gazette, Jan. 13, 1899, p. 29.

Baltimore—Length 3,700 ft. in 1892. 4,845 ft. ventilated, 1904. P.B.&W.RR.

(4) Engineering News, Oct. 20, 1892, p. 362.
(5) Railway Age, Mar. 18, 1904, p. 471.

Big Bend—Length 6,500 ft. Chesapeake & Ohio.

(6) Railroad Gazette, Feb. 20, 1903, p. 130.

Elkhorn—Length 3,000 ft. Norfolk & Western.

(7) Railroad Gazette, May 10, 1901, p. 310.
(8) Proceedings, Richmond Railroad Club, Apr. 1902.

East Mahoney—Length, 3,406 ft. Philadelphia & Reading.

(9) Railroad Gazette, Mar. 8, 1901, p. 154.

Giovi—Length 6 miles. North of Genoa.

(10) Engineering News, Sept. 18, 1902, p. 201.

Hoosac—Length 4.7 miles. Boston & Maine.

(11) Transactions, ASCE, 1890, Vol. XXIII, p. 288.

(12) Railroad Gazette, Apr. 20, 1900, p. 259.

Mersey—Length 2 miles. Liverpool.

(13) Transactions, ASCE, 1890, Vol. XXIII, p. 288.

(14) Engineering News, Oct. 18, 1894, p. 310.

(15) Minutes of Proceedings, Inst. of Civil Engineers, 1898, Vol. CXXXVI.

(16) Engineering News, Feb. 13, 1902, p. 132.

Metropolitan Tunnels—London.

(17) Engineering News, Oct. 18, 1894, p. 310.

(18) Engineering News, Apr. 14, 1898, p. 237.

(19) Railroad Gazette, Feb. 25, 1898, p. 134.

(20) Railroad Gazette, May 2, 1902, p. 333.

Park Avenue, New York—Length 2 miles. New York Central.

(21) Engineering News, Aug. 8, 1901, p. 93.

(22) Engineering News, Feb. 13, 1902, p. 132.

Pracchia—Length 9,000 ft. Between Florence and Bologna.

(23) Minutes of Proceedings, Inst. of Civil Engineers, 1898, Vol. CXXXVI.

(24) Engineering News, Aug. 31, 1899, p. 137.

St. Louis—Length 4,095 ft. Pennsylvania Lines.

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(26) Engineering News, Aug. 4, 1898, p. 79.

St. Clair—Length 6,000 ft. Grand Trunk.

(27) Railroad Gazette, Sept. 26, 1890, p. 660.

(28) Engineering News, May 12, 1892, p. 489.

(29) Engineering News, June 9, 1892, p. 584.

Boston Subway Tunnel—Length 1.8 miles.

(30) Engineering News, Feb. 4, 1897, p. 76.

(31) Railroad Gazette, Feb. 17, 1899, p. 127.

Pennsylvania Avenue Subway, Philadelphia—Length 2,711 ft. Philadelphia & Reading.

(32) Transactions, ASCE, 1902, Vol. XLVIII, p. 470.

St. Gothard—Length 9.3 miles. St. Gothard Ry.

(33) Minutes of Proceedings, Inst. of Civil Engineers, 1898, Vol. CXXXVI.

(34) Railroad Gazette, July 14, 1899, p. 504.

Simplon—Length 12.4 miles. Between Brieg and Iselle.

(35) Engineering News, Aug. 13, 1903, p. 134.

(36) Engineering News, Aug. 20, 1903, p. 154.

(No attempt has been made to list the voluminous literature on ventilation of vehicular tunnels.—A few papers which have general interest are cited)

1904. (37) "Ventilation of Tunnels".
Charles S. Churchill, Trans. ASCE, pp. 525–550, Vol. LIV. Part C.

(38) "Ventilation of Tunnels".
Francis Fox. As above, pp. 553–565.

(39) Discussion on "Ventilation of Tunnels".
As above, pp. 567–579.

1906. (40) "Ventilation of Tunnels".
Chas. S. Churchill, with discussion, Trans. ASCE, Vol. LVII, December 1906, paper 1033, pp. 227–246.

1909. (41) "Long Railway Tunnels, Construction, Ventilation and Operation".
Francis Fox (On the great town tunnels of Great Britain). Bull. Int. Ry. Cong. August 1909.

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(Further referred to as R.Q. of L.R.T.–C.V.O.) Considers tunnels in mountainous country (the Alps excepted) and great town tunnels (Great Britain excepted). Bull. Int. Ry. Cong. February 1910.

(43) "R.Q. of L.R.T.–C.V.O.".
Felix Sartiaux. (Considers methods used for submarine tunnels). Feb. 1910.

(44) "R.Q. of L.R.T.–C.V.O.".
F. Henning. (Illustrated description of the Alpine tunnels). Bull. Int. Ry. Cong. February 1910.

(45) Supplement to Report No. 1 on the "Q. of L.R.T.–C.V.O.".
Francis Fox. Bull. Int. Ry. Cong. July 1910.

(46) Report No. 5 on the "Q. of L.R.T.–C.V.O.".
Rudolph Heine. (Explains methods used in Alpine tunnels). Bull. Int. Ry. Cong. Nov. 1910.

1911. (47) "L.R.T.–C.V.O.".
Discussion on methods. Bull. Int. Ry. Cong. July 1911.

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J. V. Davies (Gives results of experimental tests and deductions drawn). Proc. ASCE, April 1912.

(49) As above.
Discussion of J. V. Davies' paper. Proc. ASCE, Aug. 1912.

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B. W. Bennett (Brief description of the forced draft system with results of some of the tests). Eng. Rec. June 8, 1912.

(51) "West Shore Weehawken Tunnel Ventilation".
(Illustrated description of the Churchill system of ventilation recently installed). Ry. Age Gazette, Aug. 1912.

1914. (52) "Ventilation of Allegheny Summit Tunnel".
F. F. Harrington. (Installation of Virginian Railway in one-mile tunnel). Eng. Rec. Sept. 9, 1914.

(53) "The Ventilation of Allegheny Summit Tunnel, Virginian Railway".
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1915. (54) "Ventilating the Stampede Tunnel of the Northern Pacific Ry.".
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J. G. Sullivan. The Cornell Civil Engineer, Vol. 25, No. 5, Feb. 1917, pp. 231–235.

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Francis Fox. Universal Eng. Vol. 28, No. 6, Dec. 1918, pp. 40–46.

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S. H. Katz and E. G. Meiter. Ry. Rev. Vol. 75, No. 11, Sept. 13, 1924, pp. 391–396. (Bureau of Mines investigates temperatures and composition of atmosphere in engine cabs while passing through tunnels).

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(63) "Ventilation Methods in Florence Lake Tunnel".
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1928. (65) "Theory and Practice in the Ventilation of Long Tunnels".
S. Weeks. Eng. and Mining Jl. Vol. 26, No. 20, Nov. 17, 1928, pp. 779–781. (This refers to removal of smoke, etc. during construction).

(66) "Atmospheric Tests in Tunnels on the Chesapeake & Ohio".
Ry. and Loco. Engr. Vol. 41, No. 4, Apr. 1928, pp. 99–101.

(67) "Investigation of Railway Tunnel Atmospheres".
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(68) "Moffat Tunnel Ventilation for Steam Locomotives".
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(69) "Tests of Atmospheres on Chesapeake & Ohio Tunnels Between Clifton Forge, Va., and Hinton, W. Va.".
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(74) "Liberty Tunnel Fan House, Pittsburgh, Pa.".
S. L. Rough. Am. Architect, Vol. 134, No. 2548, July 5, 1928, pp. 55–58. (This is a vehicular tunnel).

1929. (75) "Steam Operation No Obstacle to Use of Moffat Tunnel".
R. F. Sopris. Ry. Age, Vol. 87, No. 25, Dec. 1929, pp. 1423–1427.

(76) "Supercharged Diesel Ventilates Moffat Tunnel at 9,200 ft. Altitude".
R. F. Sopris. Oil. Engine Power, Vol. 7, No. 10, Oct. 1929, pp. 554–559.

(77) "The World's Largest Underwater Tunnel".
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1934. (81) "Designing Tunnel Ventilation for Construction Use."
C. F. Maughmer, Eng. News-Record, Vol. 112, No. 19, May 10, 1934, pp. 597–602.

Note: For items appearing in AREA publications see Index to Proceedings 1900–1915.

Appendix D

(9) SIGNS, PARTICULARLY ROADWAY SIGNS REQUIRED; CLOSE CLEARANCE SIGN

L. J. Drumeller, Chairman, Subcommittee; G. H. Burnette, J. J. Gallagher, O. N. Lackey, E. R. Lewis, W. A. Roderick.

During the convention of 1937 this committee presented for discussion the subject of "Signs, particularly Roadway Signs Required." The report was concluded with an earnest request for constructive criticism and suggestions from interested members. No criticism has been offered, and the committee presents the following report for adoption and publication in the Manual, and recommends that the subject be discontinued, excepting study under heading 904—"Design of Signs."

Definitions of Terms

Insert the following definition in the Glossary:

Roadway Sign.—Any marker displayed on or near the right-of-way for instruction or information of employees or others.

IX SIGNS

1939

901. ROADWAY SIGNS REQUIRED

The term "Roadway signs required" is interpreted to mean the minimum number and classes of signs actually necessary for the proper operation and maintenance of a line of railway. From this minimum requirement a multiplicity of signs of all manner of purposes and designs has grown up on individual railways with little semblance of uniformity of treatment or economy. These requirements have been governed to a large extent by local laws in the states through which the railways operate and to rules on the individual railways themselves. Therefore, only the signs considered necessary by this committee are included.

A—Property

(a) Land monuments. Used to define limits of right-of-way.

(b) "No Trespass" signs. Used at points where trespassing is especially dangerous or undesirable.

B—Location

(a) Mile Post. Used to afford a ready method of identification and reference to localities.

(b) Alinement Markers. Used to define the correct position of tangents, easement spirals and curves.

(c) Grade Markers. Used to establish track elevations or superelevations.

(d) Political Subdivision Signs. Used at intersections of the railway with state, county and municipal boundary lines.

C—Maintenance of Way

(a) Maintenance Limits Markers. Used to define the division of track ownership and maintenance by the railways or industry and interchange tracks between railways.

(b) Bridge or Culvert Markers. Used to identify location of bridges, trestles and culverts.

(c) Section Limits Signs. Used to mark the beginning and ends of section foreman's territory.

(d) Snow Plow Markers, including Flanger Signs. Used to indicate obstruction to snow equipment. Flanger signs warn the operator to lift the flangers. Wing markers indicate that the snow-plow wing must be closed because of close horizontal clearance. Both indications, if required at the same point, should preferably appear on one sign.

D—Transportation

(a) Speed Control Signs—both permanent and temporary. Used to warn enginemen to reduce speed of trains under permissible timetable speed due to alinement or other restrictions and including resume speed signs.

(b) Whistle Posts. Used in advance of highway grade crossings, stations, railway crossings at grade and at other points where locomotive whistles are required to be sounded by rules or law.

(c) Location Markers. Used in advance of hazards such as railway crossings at grade, yard limits, drawbridges, junctions and stations.

E—Safety

(a) Close-Clearance Markers. Used at points of close horizontal or vertical clearance, or both, such as fixed structures and at points beyond which equipment will not clear at turnouts.

(b) Fire-Risk Signs. Used to warn employees and others of inflammable material storage or underground passage of inflammables.

(c) High-Voltage Signs. Used to indicate to employees and others the presence of high-tension wires.

902. PRINCIPLES OF DESIGN AND RULES FOR USE

A—Shapes

Distinguishing shapes of signs make recognition possible from distances too great to decipher legends on the signs.

B—Dimensions

Dimensions of various groups of signs may be diversified, as are shapes, within limits determined by the legend.

C—Ground

Ground, the body of the sign, is best in sharpest contrast with the lettering. Black letters on white ground show best but, of necessity, must be varied to conform with local conditions. In some cases, to secure the sharpest contrast, the lettering on signs has been perforated. Grounds used on speed control-signs should conform, in color, to indications used on that particular railway for reducing the speed of trains.

D—Legends

Legends on signs preferably are short, consisting of characters that are as large, as plain, and as widely spaced as necessary for legibility at the required distance. Care should be observed to minimize the wording on signs. Proper spacing of characters is best determined by field tests. Bold stroked letters are preferable. These same characteristics should be observed in using signs for night indications as well as daytime, such as reflector button type.

E—Placement

Placement includes erection in a chosen or prescribed location of the sign, post and artificial base if any.

Supports for signs commonly are posts tamped solidly in ground, frequently solidified by means of rammed stones, or set in concrete. In soft earth, cleats of wood or metal projections fastened on the side at or near the butt will tend to prevent vertical displacement.

Backgrounds behind signs merit consideration. Topography may serve to improve background. To be most effective signs should be prominently displayed.

903. ECONOMY OF VARIOUS MATERIALS

A—Wood

(a) Untreated wood has been the common material for roadway signs since the inception of railroad operation. Comparatively low first cost, ready workability, light weight and plentiful supply are advantages. Wood is not easily damaged in transportation, takes paint well and serves the purpose for which many signs are required. On

the other hand, it must be repainted frequently, is subject to decay, especially near the ground line and offers only medium resistance to decay.

(b) Chemically treated wood is much more lasting at small increase in first cost, and provides a good post on which to place signs. While creosoted wood will not receive oil paints well, wood—pressure treated with one of the several salt solutions—has been used successfully.

B—Metal

(a) Scrap rail is largely used for sign and property posts and other markers. This material involves little, if any, out-of-pocket expense to the railroad. It has enough cross-sectional area to stand solidly when well placed, is stable in a concrete base and comparatively permanent. Low scrap value offsets the extravagance of weight and section, while availability is an added advantage.

(b) Scrap boiler tubes may be used as posts but have a tendency to sweat and corrode.

(c) Scrap plate for sign boards is in rather common use. Little out-of-pocket expense is involved.

(d) Sheet steel signs are frequently specified, usually bought furnished with special fastenings, sometimes painted or porcelain-enameled ready for placement.

(e) Cast iron signs with raised letters are used on a few railroads. While approaching permanency, first cost is high and a break usually means replacement.

(f) Aluminum with sand blast finish is used for flexible setting, as on telegraph poles, to good advantage. It is rust resistant.

C—Concrete

(a) Concrete is recommended where a base is needed to support the sign post.

(b) Reinforced concrete is a modern sign and post material, though it is not altogether suitable for members of restricted cross-sectional area, as water is likely to contact the reinforcement steel and cause deterioration and ultimate failure. The use of white sand and cement will reduce the paint cost.

D—Paint

Oil paints are most commonly employed. Enamel signs last longer unless misuse causes cracks or breaks. They can be cleaned instead of painted. Raised or recessed letters are readily repainted, when necessary. Spare signs are sometimes used for replacements while the sign removed is repaired and repainted in the shop. Spot field repainting in some instances is comparatively expensive. Local conditions will govern.

Conclusions

It is recommended that this report be adopted for inclusion in the Manual as recommended practice.

CLOSE-CLEARANCE SIGNS

This committee was also assigned the subject Close-Clearance Sign with a view to the adoption of a suitable sign for scant clearances.

Plans of close-clearance signs and markers were secured from a number of railroads. No two roads had designed their close-clearance signs alike but from this information close-clearance signs were developed as shown on Figs. A, B, C and D and the following conclusions reached:

1. Close-clearance signs, suitable for use under average conditions, may be used where clearances, lateral and overhead, are less than the statutory requirements.

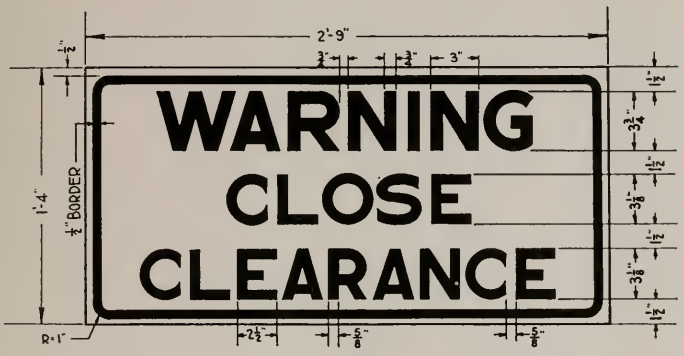


FIG. "A"

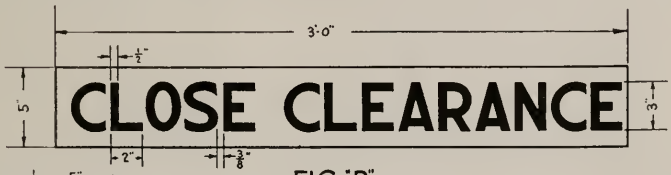


FIG. "B"
VERTICAL CLEARANCE

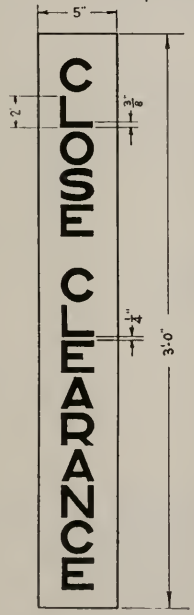


FIG. "C"
HORIZONTAL CLEARANCE

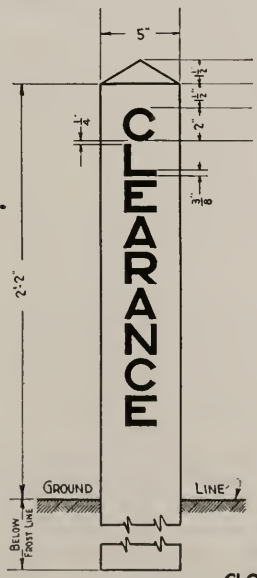


FIG. "D"
CLEARANCE POST

A.R.E.A.
CLOSE CLEARANCE SIGNS
Nov. 21, 1938.

2. The use of reflector-button type close-clearance signs is not recommended. The majority of such close-clearance signs as may be used would be located along industrial and other service tracks where the switching often necessitates the handling of cars ahead of locomotives in a pusher movement, obstructing the headlight, thereby rendering the purpose of the reflector button type sign ineffective.
3. Fig. A—close-clearance sign is designed for use in advance of restricted clearances and may be placed near the switch stand leading to the track on which the close clearance exists. They may be placed on a suitable post not less than 4 feet 6 inches from bottom of sign to ground line and not more than 7 feet.
4. Figs. B and C—close vertical and horizontal clearance signs, respectively, are designed for use at points the restricted clearance actually exists, and may be placed on the structure requiring their installation.
5. Fig. D—clearance post may be used at points beyond which equipment will not clear at turnouts.
6. Painting, construction details and material used in close-clearance signs should conform with practice in use on the individual railways using them.

This report is offered as information.

Appendix E

(10) BALLAST SECTION DESIGN

A. D. Kennedy, Chairman, Subcommittee; R. L. Dyke, J. J. Gallagher, F. L. Guy, A. R. Jones, T. P. Polson, W. A. Roderick, G. B. Wall, Jr.

The committee has prepared four ballast section plans designed for curves:

Sections No. 1—Curves and No. 2—Curves are recommended for superelevation up to and including three inches. Sections 1-A–Curves and 2-A–Curves are recommended for superelevations in excess of three inches.

As indicated thereon these sections are for prepared materials—stone, slag, and gravel having over 20 percent crushed particles.

These plans are presented for acceptance and inclusion in the Manual.

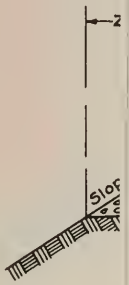
Appendix F

(11) INVESTIGATE THE USE OF ASPHALT IN BALLAST

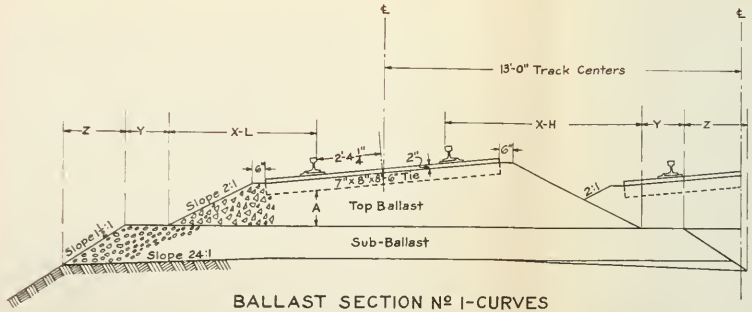
J. M. Podmore, Chairman, Subcommittee; A. P. Crosley, J. A. Given, P. J. McCarthy, J. A. Noble, Stanton Walker, C. S. Wicker.

The committee was able to find only one railroad company that used ballast below the bottom of the tie. The asphalt in the ballast was used primarily for securing good street pavement across the track. The asphalt ballast encased the rail, track fastenings and ties. The speed of trains over the track at this location was slow. The report of the engineer for the railroad states the asphalt ballast was placed 13 years ago and has given fairly satisfactory service.

The committee believes there is need for a water-proofing material which could be mixed with stone ballast that would exclude moisture and foreign matter. This material should be of such a nature it would remain plastic and workable, and not dry out with



1. Depth o
2. Under c
3. Roadbed
4. Quantiti
5. Variable

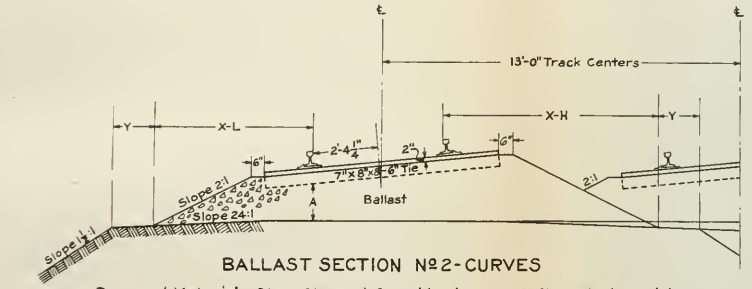


BALLAST SECTION Nº 1-CURVES

Prepared Materials: Stone, Slag and Gravel having over 20% crushed particles.

TABLE OF VARIABLES AND QUANTITIES PER 100 FEET SINGLE TRACK-FOR SECTION Nº 1-CURVES

Section	A	SUPERELEVATION																	
		1"			2"			3"			4"			5"			6"		
		X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.
1-a	16"	5'-11"	6'-1"	95	5'-10"	6'-4"	97	5'-9"	6'-7"	100	5'-8"	6'-9"	104	5'-7"	7'-0"	108	5'-6"	7'-2"	111
1-b-c	14"	5'-7"	5'-9"	82	5'-6"	6'-0"	85	5'-5"	6'-3"	88	5'-4"	6'-5"	91	5'-3"	6'-8"	95	5'-2"	6'-10"	98
1-d-e-f	12"	5'-3"	5'-5"	71	5'-2"	5'-8"	74	5'-1"	5'-11"	77	5'-0"	6'-1"	80	4'-11"	6'-4"	83	4'-10"	6'-6"	86
1-g-h-i	10"	4'-11"	5'-1"	61	4'-10"	5'-4"	63	4'-9"	5'-7"	66	4'-8"	5'-9"	68	4'-7"	6'-0"	72	4'-6"	6'-2"	75
1-j-k	8"	4'-7"	4'-9"	50	4'-6"	5'-0"	53	4'-5"	5'-3"	56	4'-4"	5'-5"	59	4'-3"	5'-8"	61	4'-2"	5'-10"	64
1-l-m	6"	4'-3"	4'-5"	41	4'-2"	4'-8"	43	4'-1"	4'-11"	46	4'-0"	5'-1"	48	3'-11"	5'-4"	51	3'-10"	5'-6"	54



BALLAST SECTION Nº 2-CURVES

Prepared Materials: Stone, Slag and Gravel having over 20% crushed particles.

TABLE OF VARIABLES AND QUANTITIES PER 100 FEET SINGLE TRACK-FOR SECTION Nº 2-CURVES

Section	A	SUPERELEVATION																	
		1"			2"			3"			4"			5"			6"		
		X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.
2-a	30"	9'-0"	9'-4"	200	8'-11"	9'-7"	204	8'-10"	9'-10"	208	8'-9"	10'-1"	212	8'-8"	10'-4"	217	8'-7"	10'-7"	222
2-b	28"	8'-7"	9'-0"	184	8'-6"	9'-3"	188	8'-5"	9'-6"	192	8'-4"	9'-9"	196	8'-3"	10'-0"	200	8'-2"	10'-3"	205
2-c-d	26"	8'-3"	8'-7"	168	8'-2"	8'-10"	171	8'-1"	9'-1"	176	8'-0"	9'-4"	180	7'-11"	9'-7"	184	7'-10"	9'-10"	189
2-e	24"	7'-10"	8'-2"	154	7'-9"	8'-5"	156	7'-8"	8'-8"	160	7'-7"	8'-11"	164	7'-6"	9'-2"	167	7'-5"	9'-5"	172
2-f	22"	7'-6"	7'-10"	139	7'-5"	8'-1"	142	7'-4"	8'-4"	146	7'-3"	8'-7"	150	7'-2"	8'-10"	154	7'-1"	9'-1"	158
2-g-h	20"	7'-1"	7'-5"	125	7'-0"	7'-8"	129	6'-11"	7'-11"	132	6'-10"	8'-2"	135	6'-9"	8'-5"	139	6'-8"	8'-8"	143
2-i	18"	6'-10"	7'-1"	111	6'-9"	7'-4"	115	6'-8"	7'-7"	119	6'-7"	7'-10"	122	6'-6"	8'-1"	125	6'-5"	8'-4"	129
2-j	16"	6'-5"	6'-9"	99	6'-4"	7'-0"	102	6'-3"	7'-3"	106	6'-2"	7'-6"	109	6'-1"	7'-9"	113	6'-0"	8'-0"	116
2-k-l	14"	6'-0"	6'-4"	86	5'-11"	6'-7"	89	5'-10"	6'-10"	93	5'-9"	7'-1"	97	5'-8"	7'-4"	100	5'-7"	7'-7"	103
2-m	12"	5'-9"	6'-0"	75	5'-8"	6'-3"	78	5'-7"	6'-6"	81	5'-6"	6'-9"	84	5'-5"	7'-0"	88	5'-4"	7'-3"	91
2-n	10"	5'-4"	5'-8"	64	5'-3"	5'-11"	66	5'-2"	6'-2"	69	5'-1"	6'-5"	73	5'-0"	6'-8"	76	4'-11"	6'-11"	79
2-o	8"	4'-11"	5'-3"	53	4'-10"	5'-6"	55	4'-9"	5'-9"	58	4'-8"	6'-0"	61	4'-7"	6'-3"	64	4'-6"	6'-6"	67
2-p	6"	4'-8"	4'-11"	43	4'-7"	5'-2"	45	4'-6"	5'-5"	48	4'-5"	5'-8"	51	4'-4"	5'-11"	54	4'-3"	6'-2"	57

NOTES

1. Depth of section to use will depend on conditions peculiar to each railroad or location.
2. Under certain conditions it may be necessary to use a depth in excess of maximum shown in tables.
3. Roadbed to be widened on high side when necessary to provide mimimum of 18 inches for Y.
4. Quantities computed on basis of 3200 ties per mile and 15% allowance for shrinkage.
5. Variables and quantities for superelevation over 3 inches are shown as information.

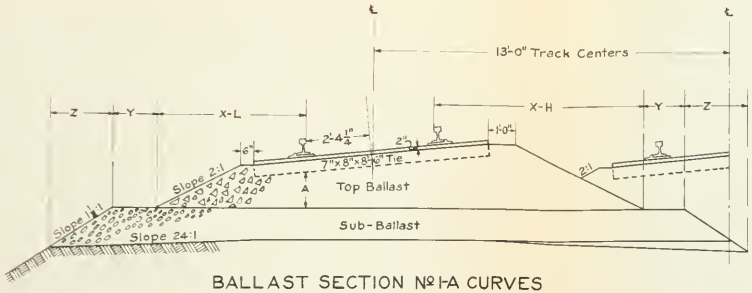
A.R.E.A.

BALLAST SECTIONS

SINGLE AND MULTIPLE TRACK-CURVES

(FOR SUPERELEVATIONS UP TO AND INCLUDING 3 INCHES)

1. Depth
2. Under
3. Roadbe
4. Quanti
5. Variabl

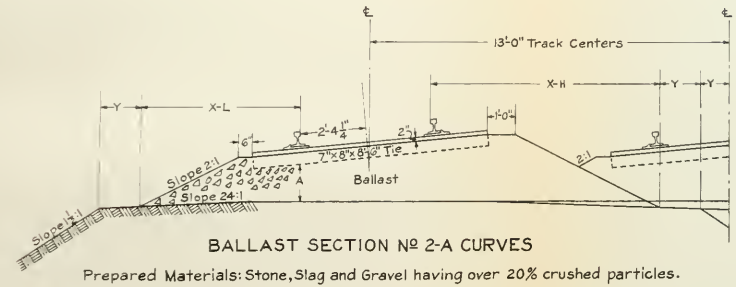


BALLAST SECTION Nº 1-A CURVES

Prepared Materials: Stone, Slag and Gravel having over 20% crushed particles.

TABLE OF VARIABLES AND QUANTITIES PER 100 FEET SINGLE TRACK-FOR SECTION Nº 1-A CURVES

Section	A	SUPERELEVATION 1"			2"			3"			4"			5"			6"		
		X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.
1-A a	16"	5'-11"	6'-7"	99	5'-10"	6'-10"	101	5'-9"	7'-1"	104	5'-8"	7'-4"	109	5'-7"	7'-6"	113	5'-6"	7'-8"	116
1-A b-c	14"	5'-7"	6'-3	86	5'-6"	6'-6"	89	5'-5"	6'-9"	92	5'-4"	7'-0"	95	5'-3"	7'-2"	100	5'-2"	7'-4"	103
1-A d-e-f	12"	5'-3"	5'-11"	74	5'-2"	6'-2"	78	5'-1"	6'-5"	81	5'-0"	6'-8"	84	4'-11"	6'-10"	87	4'-10"	7'-0"	91
1-A g-h-i	10"	4'-11"	5'-7"	64	4'-10"	5'-10"	66	4'-9"	6'-1"	69	4'-8"	6'-4"	72	4'-7"	6'-6"	76	4'-6"	6'-8"	79
1-A j-k	8"	4'-7"	5'-3"	53	4'-6"	5'-6"	56	4'-5"	5'-9"	59	4'-4"	6'-0"	62	4'-3"	6'-2"	65	4'-2"	6'-4"	68
1-A l-m	6"	4'-3"	4'-11"	43	4'-2"	5'-2"	45	4'-1"	5'-5"	49	4'-0"	5'-8"	51	3'-11"	5'-10"	54	3'-10"	6'-0"	57



BALLAST SECTION Nº 2-A CURVES

Prepared Materials: Stone, Slag and Gravel having over 20% crushed particles.

TABLE OF VARIABLES AND QUANTITIES PER 100 FEET SINGLE TRACK-FOR SECTION Nº 2-A CURVES

Section	A	SUPERELEVATION 1"			2"			3"			4"			5"			6"		
		X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.	X-L	X-H	Cu.Yds.
2-A a	30"	9'-0"	9'-10"	207	8'-11"	10'-1"	211	8'-10"	10'-4"	216	8'-9"	10'-7"	220	8'-8"	10'-10"	225	8'-7"	11'-1"	230
2-A b	28"	8'-7"	9'-6"	191	8'-6"	9'-9"	195	8'-5"	10'-0"	199	8'-4"	10'-3"	203	8'-3"	10'-6"	208	8'-2"	10'-9"	213
2-A c-d	26"	8'-3"	9'-1"	174	8'-2"	9'-4"	178	8'-1"	9'-7"	183	8'-0"	9'-10"	187	7'-11"	10'-1"	191	7'-10"	10'-4"	197
2-A e	24"	7'-10"	8'-8"	160	7'-9"	8'-11"	162	7'-8"	9'-2"	166	7'-7"	9'-5"	171	7'-6"	9'-8"	174	7'-5"	9'-11"	179
2-A f	22"	7'-6"	8'-4"	145	7'-5"	8'-7"	148	7'-4"	8'-10"	152	7'-3"	9'-1"	156	7'-2"	9'-4"	161	7'-1"	9'-7"	165
2-A g-h	20"	7'-1"	7'-11"	130	7'-0"	8'-2"	134	6'-11"	8'-5"	138	6'-10"	8'-8"	141	6'-9"	8'-11"	145	6'-8"	9'-2"	150
2-A i	18"	6'-10"	7'-7"	116	6'-9"	7'-10"	120	6'-8"	8'-1"	124	6'-7"	8'-4"	128	6'-6"	8'-7"	131	6'-5"	8'-10"	135
2-A j	16"	6'-5"	7'-3"	103	6'-4"	7'-6"	107	6'-3"	7'-9"	111	6'-2"	8'-0"	114	6'-1"	8'-3"	118	6'-0"	8'-6"	122
2-A k-l	14"	6'-0"	6'-10"	90	5'-11"	7'-1"	93	5'-10"	7'-4"	98	5'-9"	7'-7"	102	5'-8"	7'-10"	105	5'-7"	8'-1"	108
2-A m	12"	5'-9"	6'-6"	79	5'-8"	6'-9"	82	5'-7"	7'-0"	85	5'-6"	7'-3"	88	5'-5"	7'-6"	93	5'-4"	7'-9"	96
2-A n	10"	5'-4"	6'-2"	67	5'-3"	6'-5"	70	5'-2"	6'-8"	73	5'-1"	6'-11"	77	5'-0"	7'-2"	80	4'-11"	7'-5"	84
2-A o	8"	4'-11"	5'-9"	56	4'-10"	6'-0"	58	4'-9"	6'-3"	61	4'-8"	6'-6"	65	4'-7"	6'-9"	68	4'-6"	7'-0"	71
2-A p	6"	4'-8"	5'-5"	45	4'-7"	5'-8"	48	4'-6"	5'-11"	51	4'-5"	6'-2"	54	4'-4"	6'-5"	58	4'-3"	6'-8"	61

NOTES

1. Depth of section to use will depend on conditions peculiar to each railroad or location.
2. Under certain conditions it may be necessary to use a depth in excess of maximum shown in tables.
3. Roadbed to be widened on high side when necessary to provide minimum of 18 inches for Y.
4. Quantities computed on basis of 3200 ties per mile and 15% allowance for shrinkage.
5. Variables and quantities for superelevation up to 3 inches are shown as information.

A.R.E.A.

BALLAST SECTIONS

SINGLE AND MULTIPLE TRACK-CURVES

(FOR SUPERELEVATION IN EXCESS OF 3 INCHES)

age. It would seem that an asphaltic material, if it were made to pass the above requirements, would answer the purpose.

To meet the above requirements the asphalt material when mixed with stone ballast must not become brittle and should remain sufficiently elastic and pliable to give under traffic without cracking. It should remain sufficiently soft so it could be tamped if a settlement in the track occurs.

It is felt that a soft emulsified asphalt mixture is desirable, for it could easily be mixed and handled by track forces. A hot or cut-back asphalt requires heat for application and the mixture would be more difficult to handle.

A material of this nature should prove economical at the approach to open-floor bridges, under overhead structures, entrances to tunnels, station platforms, highway crossings and similar locations; where drainange is costly and where it is difficult to raise track without a large expense.

Suggested Specifications

Suggested specifications for an emulsified asphalt are as follows:

1. It shall be homogeneous and of such character that it will mix with distilled water in all proportions and shall be of such consistency that it will flow from the bung hole of a container.

2. Any material found to be defective within 90 days after date of delivery will be replaced free of cost by the seller except when separation has been caused by freezing.

3. The emulsion must be of such stability that it will remain constant and uniform while being combined and mixed with clean crushed stone sufficiently to thoroughly and uniformly coat the entire surface of each fragment while being manipulated and incorporated into the work. A test to determine the stability of the emulsion shall be made as follows:

A 500-gram mixture composed of 93 percent of clean drenched stone ½ to ¾ in. in size and 7 percent of emulsion by weight shall show no separation of the asphalt contained in the emulsion after a vigorous mixing of 3 minutes.

4. Sieve Test—Not more than 0.10 percent.

5. When distilled to a temperature of 260 degs. C. the emulsion shall yield an oil distillate of 0 to 2 percent and a total distillate of not less than 30 percent nor more than 35 percent by weight.

The residue from the foregoing distillation shall have the following characteristics:

6. Specific Gravity, 25 deg. C./25 deg. C., not less than 1.

7. Penetration at 25 degs. C., 100g., 5 sec.—100 to 200.

8. Solubility in CS_2 not less than 98.5 percent.

9. It shall have a ductility at 25 degs. C. of at least 60 cm.

10. It shall contain not more than 1.5 percent of ash.

This emulsion must be protected from freezing.

All tests should be run in accordance with ASTM methods.

Method of Application

A method of procedure for installing the mixture of emulsified asphalt and stone ballast follows:

All ties in the track should be renewed with new creosoted ties.

The ballast should be removed to the required depth below the bottom of the ties; at least eight inches is suggested.

The rail and track fastenings should be put in first class condition, making it unnecessary to disturb the track for a long time.

The ties should be coated or painted with the emulsified asphalt on the sides and ends to afford a good sealing bond between the ties and the mixture or emulsified asphalt and stone ballast.

Mixing to be done on a mixing board or preferably by a mixing machine, as used in making concrete.

Use about ⅓ to ½ gallon of emulsified asphalt to 1 cubic foot of stone ballast.

Tamp this mixture of emulsified asphalt and stone ballast under and around the ties.

The track should then be allowed to stand a day or so and all low spots tamped out before putting on the cover coat.

After this is done bring the ballast material up to about 2 inches below the top of the tie in the center of the track and slope to 4 inches below the top of the tie at the ends. The material should be thoroughly compacted by tamping.

On top of this ballast, spread and tamp a sealing or carpet covering 2 inches deep, made of a mixture of ¾-inch stone and emulsified asphalt; using about 1 gallon of emulsified asphalt to 1 cubic foot of ¾-inch stone.

On top of the ¾-inch stone, broom into the voids clear sharp wet sand thoroughly mixed with emulsified asphalt; using about 1½ to 2 gallons of emulsified asphalt to 1 cubic foot of sand.

The finished section should come to the top of the tie in the center of the track between the rails and 2 inches below the top of the tie at the ends of the tie.

Should a seam or crack occur in the seal coat or around the edges of the ties, it could readily be filled and sealed by using a can with a long spout, to pour the emulsified asphalt into these places.

The above type of construction should shed water, exclude moisture, keep out dirt, eliminate heaving and vegetable growth, tend to better hold track in line and surface; and the plastic mass should distribute the load on the roadbed more uniformly; should aid in prolonging life of the track material, help to retard end splitting of ties and result in a favorable effect on equipment.

The report is submitted as information with the recommendation that the subject be continued.

REPORT OF COMMITTEE 5—TRACK

C. J. Geyer, *Chairman;*
Lem Adams,
L. L. Adams,
C. W. Baldridge,
A. L. Bartlett,
W. H. Bettis,
W. H. B. Bevan,
F. J. Bishop,
L. H. Bond,
R. W. E. Bowler,
C. W. Breed,
E. W. Caruthers,
H. R. Clarke,
O. U. Cook,
E. D. Cowlin,
H. Q. Day,
L. W. Deslauriers,
J. A. Ellis,
H. F. Fifield,
O. H. Frick,
F. S. Hales,
H. H. Harman,
O. F. Harting,
N. M. Hench,
F. W. Hillman,
E. T. Howson,
A. F. Huber,
W. G. Hulbert,
T. T. Irving,
C. T. Jackson,
F. J. Jerome,
A. A. Johnson,
J. H. Kelly,
J. de N. Macomb,
G. M. Magee,
E. E. Martin,
L. I. Martin,
F. H. Masters,
R. E. Miller,
S. N. Mills,
W. A. Murray,
J. B. Myers,
G. A. Peabody,
W. G. Arn, *Vice-Chairman;*
A. E. Perlman,
S. H. Poore,
J. A. Reed,
O. C. Rehfuss,
C. J. Rist,
W. L. Roller,
J. R. Scatterday,
I. H. Schram
F. S. Schwinn,
J. F. Shaffer,
G. L. Sitton,
G. J. Slibeck,
G. L. G. Smith,
G. M. Strachan,
C. R. Strattman,
J. N. Todd,
Dr. Hermann von Schrenk,
H. N. West,
J. G. Wishart,
M. J. T. Zeeman,
Committee.

To the American Railway Engineering Association:

Your committee respectfully presents reports on the subjects assigned, as follows:

1. Revision of Manual (Appendix A). It is recommended that the revisions shown herein be adopted and printed in the Manual.

2. Fastenings for continuous welding of rail, collaborating with Committee 4—Rail (Appendix B). The report on this subject is offered as information.

3. Plans and specifications for track tools, collaborating with Committee 1—Roadway and Ballast, and with Committee 22—Economics of Railway Labor (Appendix C). It is recommended that Plan 8-A, timber tongs, be received as information, and that physical test for timber tongs be similarly received as information, such physical test being designed for use with Plans 8 and 8-A.

4. Plans for switches, frogs, crossings, and slip switches, collaborating with the Signal Section, and track construction in paved streets, collaborating with Committee 9—Highways on matters pertaining to track construction in paved streets (Appendix D). It is recommended that Plans 121 and 405 be adopted and printed in the portfolio of trackwork plans, and that table of contents be properly revised to cover such plans.

5. Corrosion of rail and fastenings in tunnels, collaborating with Committee 4—Rail (Appendix E). The report on this subject is offered as information.

6. Design of tie plates for RE rail sections as developed, collaborating with Committee 3—Ties and Committee 4—Rail. Progress in study—no report.

7. Practicability of using reflex units for switch lamps and targets, collaborating with Committee 10—Signals and Interlocking (Appendix F). The report on this subject is offered as information.

8. Welding of manganese castings in special trackwork, collaborating with Committee 27—Maintenance of Way Work Equipment (Appendix G). The report on this subject is offered as information.

9. Bolt tension necessary for proper supporting of joints (Appendix H). The report on this subject is offered as information.

Bulletin 409, February, 1939.

10. Lubrication of rail on curves (Appendix I). The report on this subject is offered for adoption and publication in the Manual.

11. Design of cut track spikes for use with AREA toeless joint bars (Appendix J). The report on this subject is offered for adoption and publication in the Manual.

12. Prevention of brine drippings on track structures, collaborating with Mechanical Division (Appendix K). The report on this subject is offered as information.

THE COMMITTEE ON TRACK,
C. J. GEYER, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

W. G. Arn, Chairman, Subcommittee; L. L. Adams, W. H. B. Bevan, C. W. Breed, J. A. Ellis, F. W. Hillman, E. T. Howson, A. A. Johnson, J. de N. Macomb, S. N. Mills, J. B. Myers, I. H. Schram, G. L. G. Smith, J. G. Wishart, M. J. T. Zeeman.

The committee submits for revision the following plans adopted in March, 1936:

Plan No 1—Clay Pick—Revised to show contour of back

Plan No. 2—Tamping Pick—Revised to show contour of back

Plan No. 4—Track Wrenches for A.S.A. Heavy Nuts—Revised note to show width of nut instead of size of bolt

Plan 4A—Track Wrenches for A.S.A. Regular Nuts—Revised note to show width of nut instead of size of bolt

Plan No. 11—Claw Bar Design No. 1—Revised to show additional dimensions, correct weight and revised tolerance

Plan No. 11A—Claw Bar Design No. 2—Revised as to tolerance

Plan No. 16—Track Chisel Design No. 1—Change of radius of cutting edge from ¾ in. to 1 in.

Plan No. 17—Track Chisel Design No. 2—Change of radius of cutting edge from ¾ in. to 1 in.

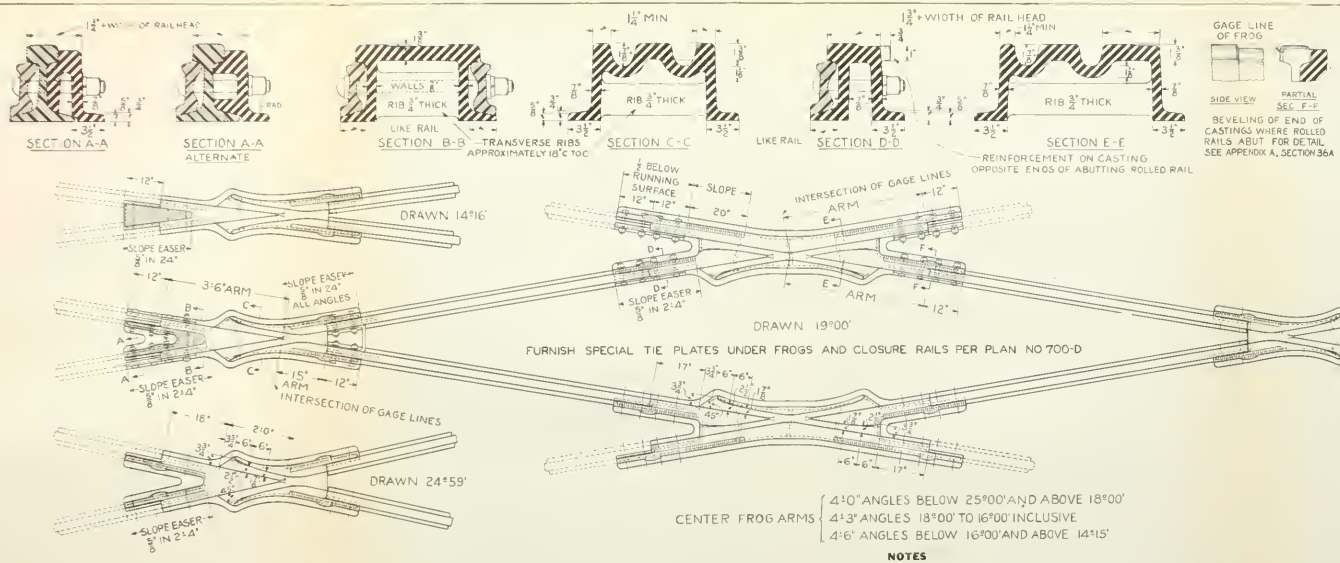
These revisions as submitted are for the purpose of supplementing the information shown on plans and to assist in the manufacture of the tools involved. No change in design is contemplated.

Plans Nos. 774 and 775—Crossings With Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles Below 25 deg. to 8 deg. 10 min., Inclusive.

Some time ago it was suggested that these plans ought to be made more definite by fixing the lengths of the frogs, and it was also brought out in the discussions that the design shown on Plan No. 774, for angles below 25 deg. and above 14 deg. 15 min., has not proved altogether satisfactory.

Upon going into the matter in detail it was developed that it is extremely uneconomical to make these solid manganese steel frogs long enough to accommodate the long 6-hole joint bars now used by some roads, and it was decided to offer designs based on the use of 24-in. joint bars, all of which would be furnished complete with bolts by the maker of the crossing.

From the various study plans which were made and discussed by the committee, a number of improvements were suggested, all of which, together with definite frog lengths, have been incorporated in the following revised plans, which are offered for recommended practice:—



DETAILS OF HEEL ENDS OF END FROGS TO BE MADE TO SUIT ANGLE DETAILS SHOWN ABOVE ARE TYPICAL FOR ANGLES DRAWN

NOTES

1—DETAIL OF JOINT BARS—Purchaser shall in all cases supply details of joint bars, especially as to size and location of holes required in rail ends and as to size and location of spike notches if any for plate punching.

2—Unless otherwise specified crossings shall be furnished as illustrated and to the following details—

(a) HEIGHT OF CROSSING. Height of lower detail of external arms and section of interior rails shall conform to the highest connecting rail, not less than 6" recommended for heavy service.

(b) CASTING EXTENSION— To be 12" at all ends, with specified joint drilling. (If three hole drilling be standard for the rail specified, drereard the third hole.)

(c) JOINT BARS 24" Bars which are standard for the rail specified (but only 24" long even though three hole drilling be standard) shall be furnished complete with bolts for all interior and exterior joints except that U-Bars with bolts shall be furnished for the toe ends of the end frogs.

(d) BOLTS—High tensile steel and generally per Section 1402, Appendix "A", except that diameter shall be same as standard track bolt for joint bar detail specified.

All bolts shall have effective head locks brads which are against joint bars generally to be of the track bolt type. Where brads are against casting it shall be designed to prevent bolts from turning.

(e) PLATES—Tie plates per Plan No 700-D

3 ADDITIONAL EQUIPMENT

(a) PLATES—Any applicable style per Plans No 700-D and 700-E.

4—GENERAL

(a) For application of AREA Crossing Designs and recommended practice, see Plan No 700.

(b) GAGES AND FLANGEWAYS for tangent track see Plan No 790 for curved track, see Plan No 791. For flangeway contours see Plan No 600-B For permissible variations in manufacture, see Section 33, Appendix A.

(c) CONNECTING RAILS. It is recommended that new rails of the highest connecting section be installed against all external arms of the crossing and compromise joints installed at the end of these rails, if necessary.

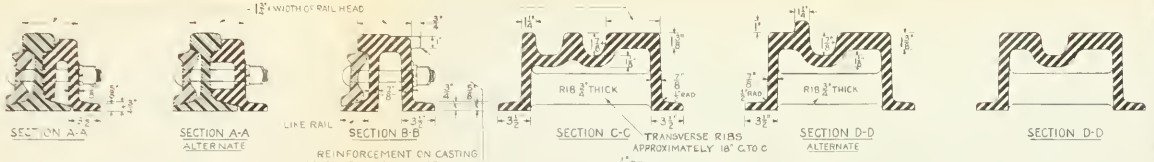
5 SPECIFICATIONS See Appendix A.

A. R. E. A.

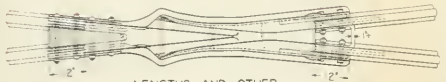
CROSSING WITH SOLID MANGANESE STEEL FROGS AND INTERIOR ROLLED CLOSURE RAILS. ANGLES BELOW 25° 00' AND ABOVE 14° 15' SINGLE RAIL CONSTRUCTION.

PLAN NO. 774

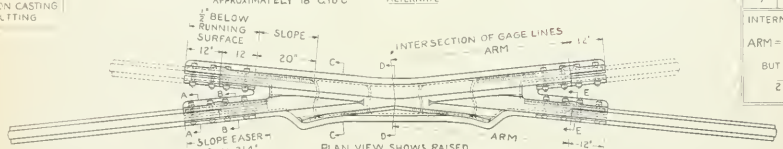
Adopted March, 1927 Revised March, 1928, March, 1934 March, 1939



BEVELING OF ENDS OF CASTINGS WHERE ROLLED RAILS ABUT
FOR DETAIL SEE APPENDIX A, SECTION 36A



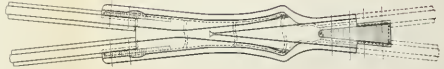
LENGTHS AND OTHER
END FROG DETAILS PER PLAN NO 670 DESIGN 2
UNLESS SHOWN DIFFERENT HEREON

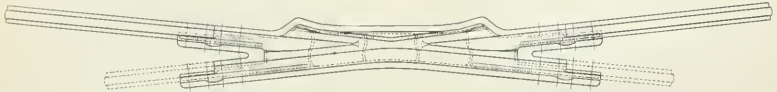


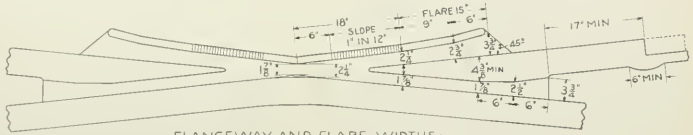
PLAN VIEW SHOWS RAISED GUARD, WHICH IS ALTERNATE CONSTRUCTION

FURNISH SPECIAL TIE PLATES UNDER FROGS AND CLOSURE RAILS PER PLAN NO 700-D

DRAWN 11-25







FLANGEWAY AND FLARE WIDTHS

NOTES

1—DETAIL OF JOINT BARS—Purchaser shall in all cases supply details of joint bars, especially as to size and location of holes required in rail ends and as to size and location of spike notches, if any, for plate punching
2—Unless otherwise specified crossings shall be furnished as illustrated and to the following details —
a HEIGHT OF CROSSING—Heights of frogs, details of external arms and section of interior rails shall conform to the highest connecting rail not less than 6" recommended for heavy service
b CASTING EXTENSIONS—To be 12" at all ends with specified joint drilling (If three hole drilling be standard for the rail specified disregard the third hole)
c JOINT BARS—24" Bars which are standard for the rail specified (but only 24" long even though three hole drilling be standard) shall be furnished complete with bolts for all interior and exterior joints, except that U-Bars with bolts shall be furnished for the toe ends of the end frogs
d BOLTS—High tensile steel and generally per Section 1402 Appendix "A" except that diameter shall be same as standard track bolt for joint bar detail specified
All bolts shall have effective head locks, heads which are against joint bars generally to be of the track bolt type Where heads are against casting it shall be designed to prevent bolts from turning
e PLATES—Tie plates per Plan No 700-D
3—ALTERNATES AND ADDITIONAL EQUIPMENT
a END FROGS—Design 1 per Plan No 670
b END FROGS—Solid Self Guarded per Plan No 640
c RAISED GUARDS—For Center Frogs
d WING WHEEL RISERS—For End Frogs
e PLATES—Any applicable style per Plans No 700-D and 700-E
4—GENERAL
a For application of AREA Crossing Designs and recommended practice, see Plan No 300
b GAGES AND FLANGEWAYS for tangent track see Plan No 790 for curved track see Plan No 791 For flangeway contours see Plan No 605-B For permissible variations in manufacture, see Section 33 Appendix A
c CONNECTING RAILS—It is recommended that new rails of the highest connecting section be installed adjacent to external arms of the crossing and compromise joints installed at the end of these rails, if necessary
d CENTER FROG POINTS—To conform to details on Plan No 753
5—SPECIFICATIONS—See Appendix "A"

CENTER FROGS		
Nº	ANGLE	ARMS
4	14°15'00"	4'6"
4½	12°40'50"	4'9"
5	11°25'16"	5'0"
5½	10°23'20"	5'4"
6	9°31'38"	5'9"
6½	8°47'50"	6'2"
7	8°10'16"	6'7"

INTERMEDIATE ANGLES

$$ARM = \frac{9\frac{1}{2}\ \text{INS}}{2\ \text{SIN}\ \frac{\text{ANGLE}}{2}} - 12"$$

BUT NOT LESS THAN

$$\frac{6\frac{1}{4}\ \text{INS}}{2\ \text{SIN}\ \frac{\text{ANGLE}}{2}} + 2'5"$$

A. R. E. A.

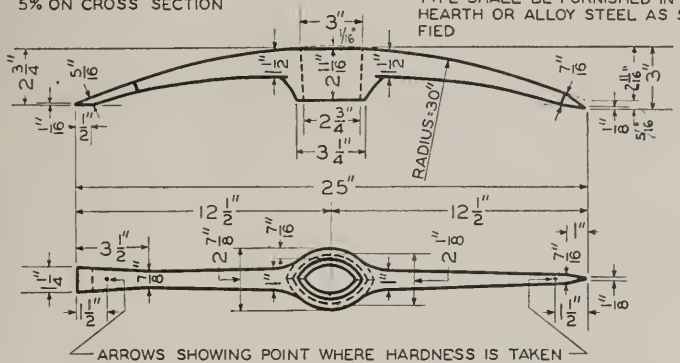
CROSSING WITH SOLID MANGANESE STEEL FROGS AND INTERIOR ROLLED CLOSURE RAILS. ANGLES 14° 15′ TO 8° 10′ INCL. SINGLE RAIL CONSTRUCTION.

PLAN NO. 775

METALLURGICAL LIBRARY

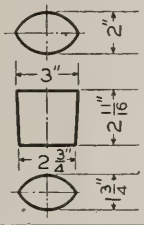
TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

DOUBLE POINTED PICK SHALL BE FURNISHED WHEN SPECIFIED EITHER TYPE SHALL BE FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED



ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN

DETAIL OF EYE



BRINELL 425 - 500
FOR O.H. STEEL ONLY.

APPROX WT 7 LB.

NOTE:-
CURVATURE OF BACK SHALL BE CONTINUOUS AND OF 30" RADIUS EXCEPT WHERE FLATTENED OVER THE EYE. RADIUS TO BE COINCIDENT WITH CENTER LINE OF EYE.

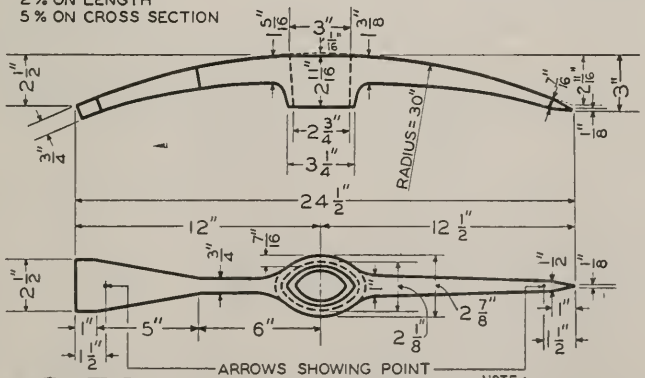
A. R. E. A.

CLAY PICK

MAR. 1939 PLAN NO. 1.

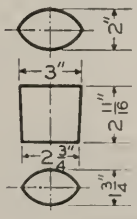
TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

NOTE:- FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED.



ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN

DETAIL OF EYE



BRINELL 425 500
FOR O.H. STEEL ONLY.

APPROX WT 8 LB

NOTE :-
CURVATURE OF BACK SHALL BE CONTINUOUS AND OF 30" RADIUS EXCEPT WHERE FLATTENED OVER THE EYE. RADIUS TO BE COINCIDENT WITH CENTER LINE OF EYE.

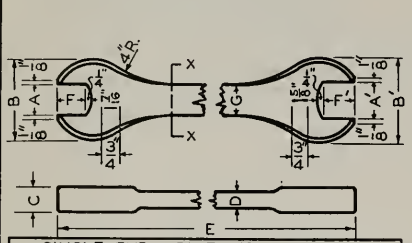
A. R. E. A.

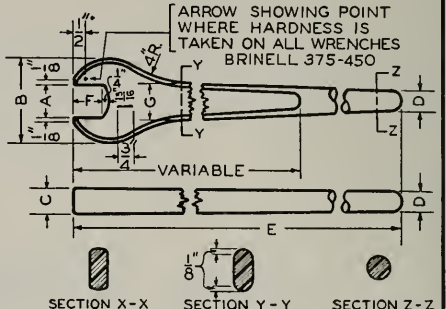
TAMPING PICK

MAR. 1939 PLAN NO. 2.

TOLERANCE—
2% ON LENGTH
5% ON CROSS SECTION

ALL WRENCH JAWS SHALL BE MILLED TO DIMENSIONS SHOWN





SINGLE END — DIMENSIONS IN INCHES

BOLT SIZES	WIDTH OF NUT	A MIN	A MAX	B	C	D	E	F	G
3/4	1 1/4	1.257	1.330	3 1/2	15/16	3/4	30	1 1/4	1 1/2
7/8	1 7/16	1.445	1.519	4	15/16	3/4	36	1 1/4	1 1/2
1	1 5/8	1.634	1.709	4	15/16	7/8	42	1 3/8	1 1/2
1 1/8	1 13/16	1.822	1.898	4 1/2	15/16	7/8	48	1 3/16	1 1/2
1 1/4	2	2.011	2.088	4 1/2	1	7/8	48	1 3/4	1 1/2
1 3/8	2 3/16	2.199	2.277	5	1	7/8	54	1 15/16	1 1/2

DOUBLE END — DIMENSIONS IN INCHES

BOLT SIZES	WIDTH OF NUT	A MIN	A MAX	A' MIN	A' MAX	B	B'	C	D	E	F	F'	G
3/4 & 7/8	1 1/4 & 1 7/16	1.257	1.330	1.445	1.519	3 1/2	4	15/16	1/2	36	1 1/4	1 1/4	1 1/2
7/8 & 1	1 7/16 & 1 5/8	1.445	1.519	1.634	1.709	4	4	15/16	1/2	42	1 1/4	1 3/8	1 1/2
1 & 1 1/8	1 5/8 & 1 13/16	1.634	1.709	1.822	1.898	4	4 1/2	15/16	9/16	48	1 3/8	1 9/16	1 1/2
1 1/8 & 1 1/4	1 13/16 & 2	1.822	1.898	2.011	2.088	4 1/2	4 1/2	*	9/16	48	1 3/16	1 3/4	1 1/2
1 1/4 & 1 3/8	2 & 2 3/16	2.011	2.088	2.199	2.277	4 1/2	5	1	9/16	48	1 3/4	1 15/16	1 1/2

* C = 15/16 ON 1 1/8 END, 1 ON 1 1/4 END.

WIDTH OF NUT SHALL BE STAMPED PLAINLY ON ONE SIDE OF HEAD IN POSITION AS SHOWN.

SINGLE END WRENCH WILL BE FURNISHED WITH END TAPERED FOR LAST 6" TO 1/2" DIA. AT END WHEN SPECIFIED.

A.S.A.-HEAVY NUTS, ARE SAME AS, AND SUPERSEDE FORMER U.S. STD.

A. R. E. A.

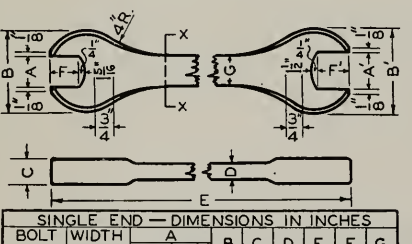
TRACK WRENCHES

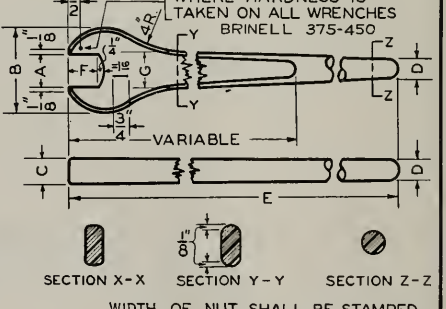
FOR A.S.A - HEAVY NUTS

MAR. 1939 PLAN NO. 4.

TOLERANCE—
2% ON LENGTH
5% ON CROSS SECTION

ALL WRENCH JAWS SHALL BE MILLED TO DIMENSIONS SHOWN





SINGLE END — DIMENSIONS IN INCHES

BOLT SIZES	WIDTH OF NUT	A MIN	A MAX	B	C	D	E	F	G
3/4	1 1/8	1.132	1.205	3 3/8	15/16	3/4	30	1 1/8	1 1/2
7/8	1 5/16	1.320	1.394	3 7/8	15/16	3/4	36	1 1/8	1 1/2
1	1 1/2	1.508	1.583	3 7/8	15/16	7/8	42	1 1/4	1 1/2
1 1/8	1 11/16	1.696	1.771	4	15/16	7/8	48	1 7/16	1 1/2
1 1/4	1 7/8	1.885	1.961	4 3/8	1	7/8	48	1 5/8	1 1/2
1 3/8	2 1/16	2.073	2.150	4 7/8	1	7/8	54	1 13/16	1 1/2

DOUBLE END — DIMENSIONS IN INCHES

BOLT SIZES	WIDTH OF NUT	A MIN	A MAX	A' MIN	A' MAX	B	B'	C	D	E	F	F'	G
3/4 & 7/8	1 1/8 & 1 5/16	1.132	1.205	1.320	1.394	3 3/8	3 7/8	15/16	1/2	36	1 1/8	1 1/8	1 1/2
7/8 & 1	1 5/16 & 1 1/2	1.320	1.394	1.508	1.583	3 7/8	3 7/8	15/16	1/2	42	1 1/8	1 1/4	1 1/2
1 & 1 1/8	1 1/2 & 1 11/16	1.508	1.583	1.696	1.771	3 7/8	4	15/16	9/16	48	1 1/4	1 7/16	1 1/2
1 1/8 & 1 1/4	1 11/16 & 1 7/8	1.696	1.771	1.885	1.961	4	4 3/8	*	9/16	48	1 7/16	1 5/8	1 1/2
1 1/4 & 1 3/8	1 7/8 & 2 1/16	1.885	1.961	2.073	2.150	4 3/8	4 7/8	1	9/16	48	1 5/8	1 13/16	1 1/2

* C = 15/16 ON 1 1/8 END, 1 ON 1 1/4 END

WIDTH OF NUT SHALL BE STAMPED PLAINLY ON ONE SIDE OF HEAD IN POSITION AS SHOWN.

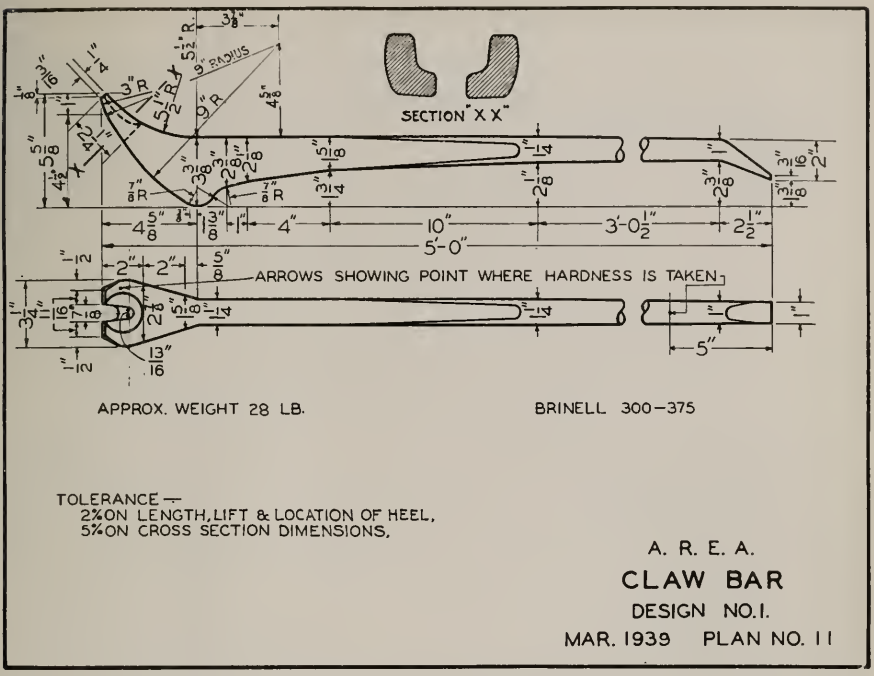
SINGLE END WRENCH WILL BE FURNISHED WITH END TAPERED FOR LAST 6" TO 1/2" DIA. AT END WHEN SPECIFIED

A. R. E. A.

TRACK WRENCHES

FOR A.S.A.- REGULAR NUTS

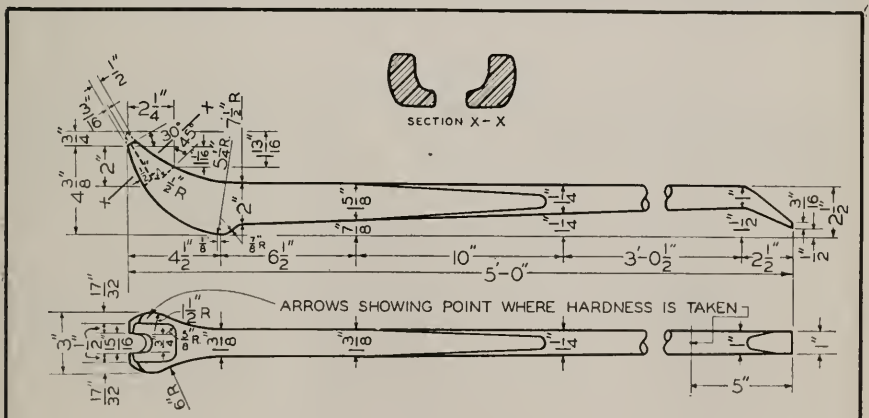
MAR. 1939 PLAN NO. 4-A



APPROX. WEIGHT 28 LB. BRINELL 300–375

TOLERANCE —
2% ON LENGTH, LIFT & LOCATION OF HEEL,
5% ON CROSS SECTION DIMENSIONS.

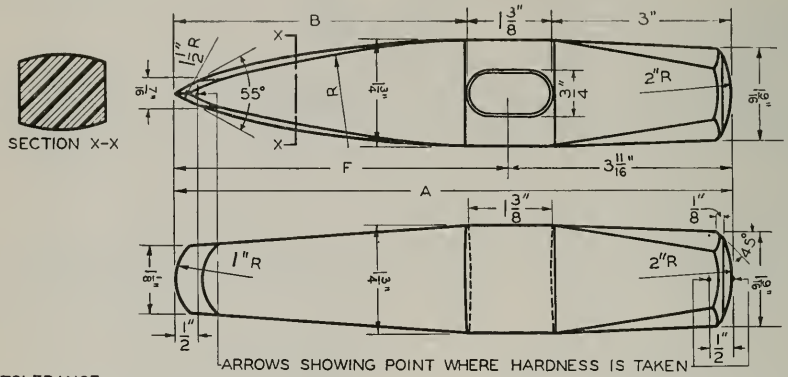
A. R. E. A.
CLAW BAR
DESIGN NO. 1.
MAR. 1939 PLAN NO. 11



APPROX. WEIGHT 28 LB BRINELL 300–375

TOLERANCE —
2% ON LENGTH, LIFT & LOCATION OF HEEL.
5% ON CROSS SECTION.

A. R. E. A.
CLAW BAR
DESIGN NO. 2.
MAR. 1939 PLAN NO. 11-A

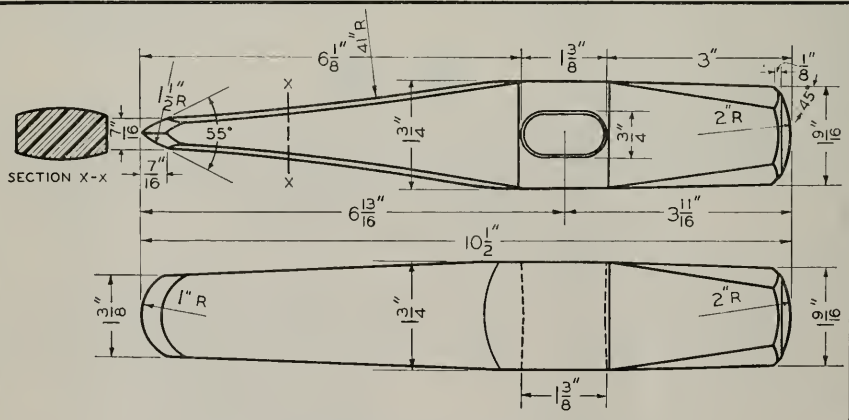


TOLERANCE—
2% ON LENGTH, 5% ON CROSS SECTION.
EYE TAPERED TO CENTER
4° ON LONG DIAMETER
3° ON SHORT DIAMETER.
FURNISHED IN OPEN HEARTH, OR
ALLOY STEEL AS SPECIFIED

BRINELL { POINT 477-532 / HEAD 286-340 } FOR O. H STEEL ONLY

APPROX WT	A	B	F	R
5 1/4 LBS.	9 1/4"	4 7/8"	5 9/16"	18 7/8"
6 1/4 LBS	10 1/2"	6 1/8"	6 13/16"	33 1/4"

A. R. E. A.
TRACK CHISEL
DESIGN NO. 1.
MAR. 1939 PLAN NO 16.



THIS DESIGN FURNISHED IN ALLOY STEEL ONLY
APPROX. WEIGHT 5½ LB.

TOLERANCE—
2% ON LENGTH, 5% ON CROSS SECTION.
EYE TAPERED TO CENTER
4° ON LONG DIAMETER
3° ON SHORT DIAMETER

A. R. E. A.
TRACK CHISEL
DESIGN NO. 2.
MAR. 1939 PLAN NO. 17.

Plan No. 774—Crossing with Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles Below 25 deg. and Above 14 deg. 15 min., Single-Rail Construction.

Plan No. 775—Crossing with Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles Below 14 deg. 15 min. to 8 deg. 10 min. Inclusive, Single-Rail Construction.

Appendix B

(2) FASTENINGS FOR CONTINUOUS WELDING OF RAIL

Collaborating with Committee 4—Rail

G. M. Magee, Chairman, Subcommittee; Lem Adams, L. L. Adams, C. W. Baldridge, A. L. Bartlett, W. H. B. Bevan, W. H. Bettis, F. J. Bishop, O. U. Cook, E. D. Cowlin, J. A. Ellis, H. F. Fifield, F. S. Hales, H. H. Harman, N. M. Hench, E. T. Howson, J. de N. Macomb, W. A. Murray, J. B. Myers, J. A. Reed, J. R. Scatterday, G. J. Slibeck, C. R. Strattman.

In the first report on the assignment "Fastenings for Continuous Welding of Rail" (AREA Proceedings Vol 37, Page 470) the Subcommittee gave a brief history of the use of continuous welded rail in this country and abroad. An inspection was made of continuous welded rail, secured with M. & L. type fastenings, on the Delaware & Hudson Railroad, and it was decided that the work of the subcommittee could best be continued by making inspections, and reports of the service performance, of continuous welded rail with various types of fastenings.

Accordingly, in the work for the following year, the continuous welded rail installation on the Bessemer & Lake Erie Railroad was inspected and reported upon (AREA Proceedings Vol. 38, Page 493). In this installation the rail was secured with GEO type fastenings.

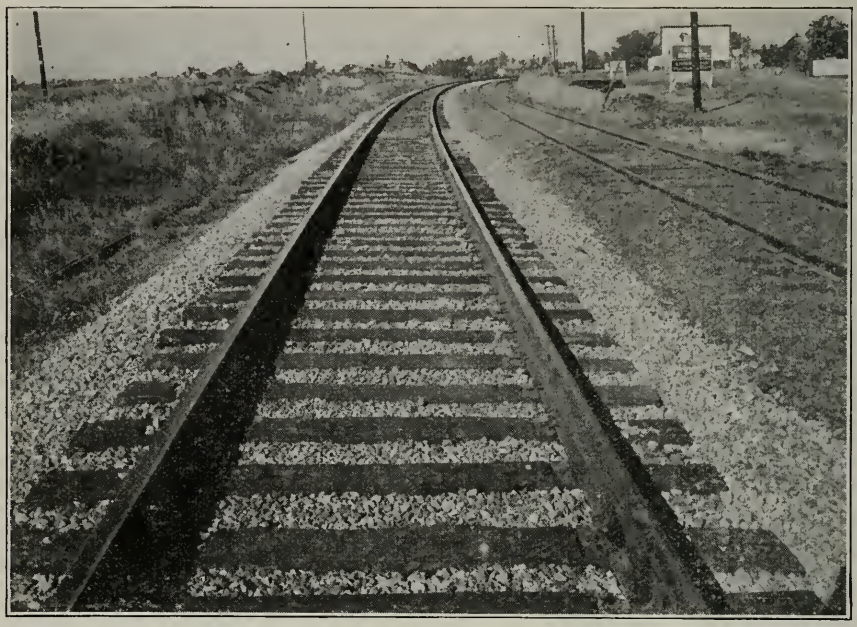
This year the subcommittee has inspected and presents the following report on an installation of continuous welded rail on the Central of Georgia Railway. This installation is of particular interest because no special type of rail fastening was used, the rails being held in place by double-shouldered tie plates, cut spikes, and a limited number of rail anchors, as will be later described.

A follow-up report on the Delaware & Hudson and the Bessemer & Lake Erie installations is given as a matter of information, which includes the advices of the respective maintenance officers of these two railways on the service performance to date. The subcommittee also has an assignment to recommend a design for a screw spike which may be used to secure the tie plate to the tie independently of the rail fastening. A progress report is presented upon this assignment.

Installation of Continuous Welded Rail on the Central of Georgia Railway Near Lovejoy, Ga.

Description of the Welded Track

The subcommitee inspected this installation on October 26, 1938. The installation is approximately one-half mile in length, on single-track main line railway carrying heavy, fast freight and passenger traffic. The rail is 112-lb. RE section and the 39-ft. lengths were welded before being placed in track, with oxy-acetylene V-type butt welds. After being welded together the rails were pulled into position by means of a locomotive and cable, and the closure welds made. A pair of strap joint bars was provided at each weld as a safety measure in the event breakage of a weld should occur. These bars are



View of Installation of Continuous Rail on Central of Georgia Railway.

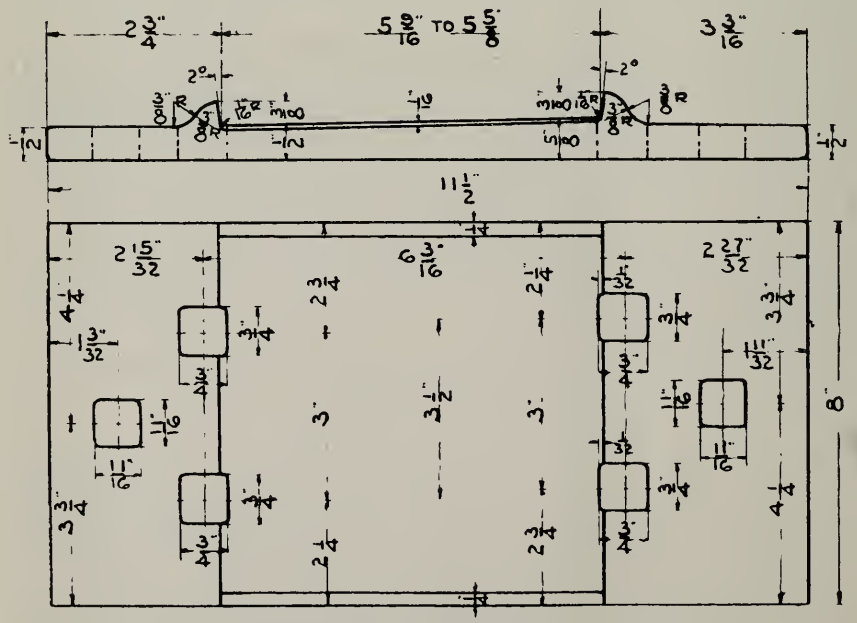


Fig 1.—Double-Shoulder Tie Plate with Crown Rail Seat.

24 in. long, secured with two bolts, placed in the end holes. The bars do not fit tightly into the fishing surfaces of the rail, but are intended only to hold the rail in alinement in the event of a weld failure.

The welded rail rests in 8-in. by 11½-in. double-shouldered tie plates, the design of which is shown in Fig. 1. One cut spike was driven each side of the rail at each tie plate on the tangent track and, in addition, a cut spike was driven in each of the outer holes of the tie plate to secure the tie plate to the tie independently of the cut spike rail fastenings. (See Fig. 9.) On the curved portion of the track an additional cut spike was driven on the gage side of the rail thus providing three cut spikes through each tie plate to secure the rail, and two to secure the plate to the tie.

The joint bars at each end of the welded rail are 24-in., 4-hole toeless bars of usual design, secured with 1-in. heat-treated bolts and spring washers, with one exception. At the east end of the south rail the bolts had sheared off following an abrupt drop in temperature, and a special 8-hole joint was provided by welding two bars together end to end for each side of the rail. Only 6 bolts were actually placed in the joint, however.

Rail anchors originally were not contemplated. However, shortly after the rail was laid, anchors were provided for a distance of approximately 250 ft. at each end of the test section. Within this distance, 6 anchors per rail length were applied. In the spring the anchors are placed to resist expansion of the rail, and in the fall they are reset to resist contraction during the winter.

The ties were not replaced out-of-face at the time of installation of the welded rail, but renewals were made as required. The ties are all treated, in first class condition, and spaced 24 per 39-ft. rail length.

The ballast consists of crushed slag from nearby steel mills. It is not as heavy as crushed rock or gravel, weighing approximately 2,000 lb. per cu. yd. The tie cribs were filled approximately level with the tops of the ties and an ample ballast shoulder provided.

At the time of the subcommittee inspection the track was in excellent line and surface. At various locations along the track it was apparent that some longitudinal movement, perhaps as much as one inch, had recently occurred, as evidenced by marking of the spikes on the rail base. Those ties at the ends of the welded track against which the rail anchors pressed had been moved somewhat in the ballast as evidenced by the position of the ballast in the cribs each side of the particular ties.

Measurements of Rail Movements and Temperature Strains

In the last subcommittee report, AREA Proceedings, Vol. 38, pp. 493–495, a theoretical explanation was presented of rail temperature movements and stresses in continuous welded rail, with particular regard to the holding strength of the fastenings. It was shown that if rail were completely held against longitudinal movement, for each degree of temperature change from the laying temperature, an internal stress of 195 lb. per sq. in. would be produced; tension or compression depending upon whether the temperature decreased or increased. The analysis also described the manner in which the joint restraint, or holding force transmitted through the joint at each end of the welded rail, and the tie restraint, or holding force provided by each tie through its fastening, might combine to develop sufficient holding force to prevent any rail longitudinal movement except for a limited distance at each end of the welded rail. It was pointed out that the amount of end movement depended upon the amount of unrestrained temperature movement, and a formula was developed whereby the end movement could be calculated if the temperature change, joint restraint, and tie restraints were known. The amount of joint and tie restraint can only be determined by experiment. The work being carried out under the direction of Dr. A. N. Talbot in the investigations of the Special Committee on Stresses

in Railroad Track has developed data on the joint and tie restraint with the M. & L. and GEO type fastenings. Measurements of longitudinal rail movement and temperature strains made on the Central of Georgia installation give interesting data on joint and tie restraints with cut spike rail fastenings and a limited number of anchors.

The subcommittee desires to express appreciation to Mr. R. R. Cummins, assistant general manager, Mr. R. L. Cook, office manager, and Mr. G. W. Benson, track supervisor of the Central of Georgia for furnishing the plan of the test track and measurements of rail movements and temperature stresses.

Fig. 2 is a plan showing the arrangement of the test section and the location of monuments established for determining lateral and longitudinal movements of the rail at different temperatures.

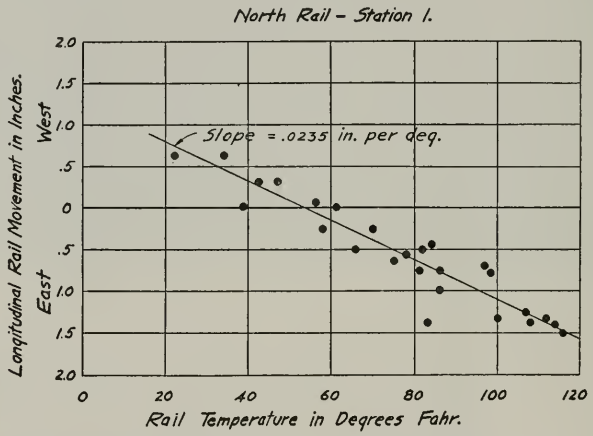


Fig. 4.—Measured Longitudinal Movement Near Ends of Welded Rail at Various Temperatures — October, 1937–October, 1938.

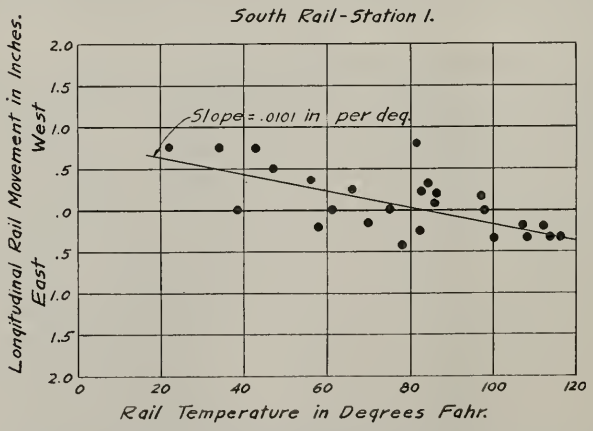
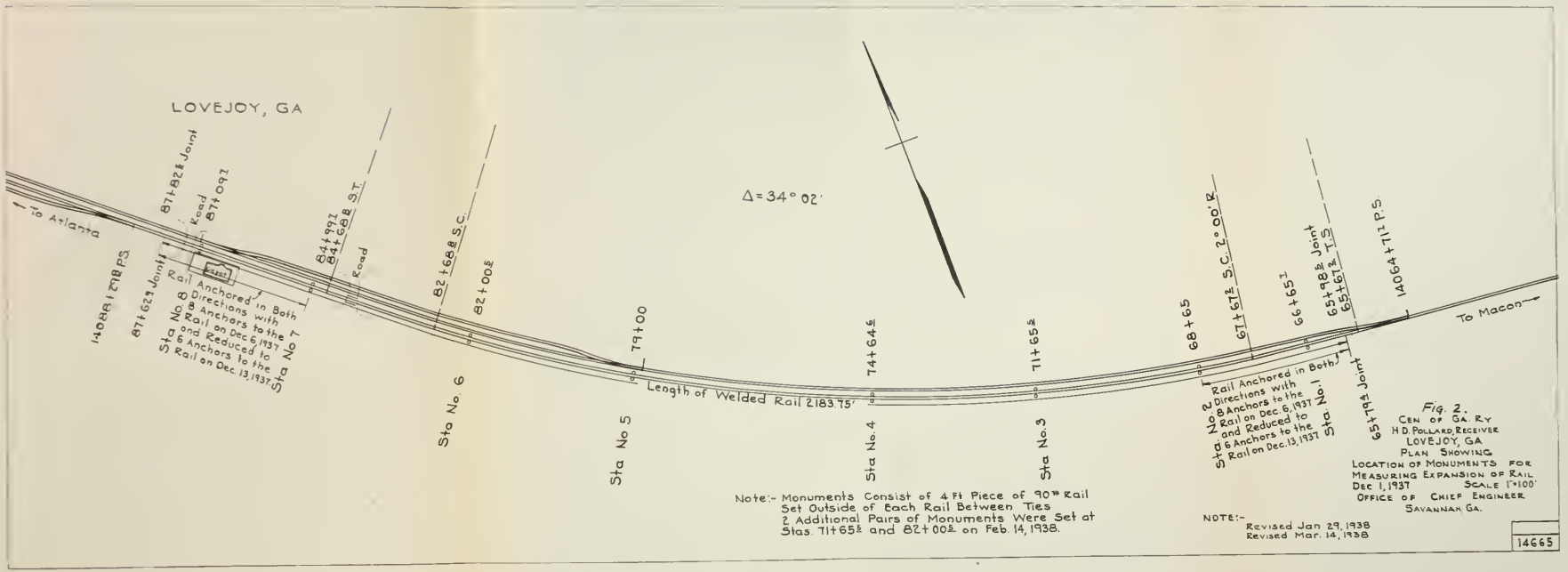


Fig. 5.—Measured Longitudinal Movement Near Ends of Welded Rail at Various Temperatures — October, 1937–October, 1938.

To Atla


LOVEJOY, GA
To Atlanta
140AR 1.718 P.S.
87+62.3 Joint
87+82.8 Joint
87+09.7
Road
Rail Anchored in Both Directions with No 8 Anchors to the Rail on Dec. 6, 1937 and Reduced to 6 Anchors to the Rail on Dec. 13, 1937
Sta No 7
84+99.1
84+68.8 S.T.
Road
82+68.8 S.C.
82+00.8
Sta No 6
79+00
Sta No 5
Length of Welded Rail 2183.75'
Δ = 34° 02'
74+64.8
Sta No. 4
71+65.8
Sta No.3
68+65
67+61.8 S.C. 2°00' R
66+65.1
65+98.8 Joint
65+61.8 T.S.
65+19.8 Joint
Rail Anchored in Both Directions with No 8 Anchors to the Rail on Dec. 6, 1937 and Reduced to 6 Anchors to the Rail on Dec. 13, 1937
Sta No 1
1406+71.1 P.S.
To Macon
Note:- Monuments Consist of 4 Ft Piece of 90# Rail Set Outside of Each Rail Between Ties
2 Additional Pairs of Monuments Were Set at Stas. 71+65.8 and 82+00.8 on Feb. 14, 1938.
NOTE:-
Revised Jan 29, 1938
Revised Mar. 14, 1938
Fig. 2.
CEN OF GA R.Y
H.D. POLLARD, RECEIVER
LOVEJOY, GA
PLAN SHOWING
LOCATION OF MONUMENTS FOR MEASURING EXPANSION OF RAIL.
DEC 1, 1937 SCALE 1"=100'
OFFICE OF CHIEF ENGINEER
SAVANNAH GA.
14665

CENTRAL OF GEORGIA RAILWAY

LOVEJOY, GEORGIA

LATERAL AND LONGITUDINAL MOVEMENT OF WELDED RAIL

FIG. 3

TEMP RAIL LAID	
NORTH RAIL	SOUTH RAIL
78°F	80°F

RAIL LAID OCTOBER 1937.

NOTE:- "Base" measurements shown under "lateral movement" represent the distances from monuments to the outside base of nearest rail when monuments were set at stations 1-2-4-5-Tand 8 on 12/1/37 and at Stations 3and 6 on 2/15/38.

NOTE:- Monuments at stations 3and 6 were set on 2/15/38 with 0" markings for measuring longitudinal movement. Recorded longitudinal readings however have been adjusted to show longitudinal movement based on an interpolated longitudinal movement for 2/15/38 as if monuments had been set on 12/1/37 with "0" markings.

DATE	TIME	WEATHER	STATION No. 8					STATION No. 7					STATION No. 6					STATION No. 5					STATION No. 4					STATION No. 3					STATION No. 2					STATION No. 1					OPEN JOINTS		REMARKS
			TEMP °F	SOUTH RAIL MOVEMENT LATERAL	SOUTH RAIL MOVEMENT LONGTDL	NORTH RAIL MOVEMENT LATERAL	NORTH RAIL MOVEMENT LONGTDL	TEMP °F	SOUTH RAIL MOVEMENT LATERAL	SOUTH RAIL MOVEMENT LONGTDL	NORTH RAIL MOVEMENT LATERAL	NORTH RAIL MOVEMENT LONGTDL	TEMP °F	SOUTH RAIL MOVEMENT LATERAL	SOUTH RAIL MOVEMENT LONGTDL	NORTH RAIL MOVEMENT LATERAL	NORTH RAIL MOVEMENT LONGTDL	TEMP °F	SOUTH RAIL MOVEMENT LATERAL	SOUTH RAIL MOVEMENT LONGTDL	NORTH RAIL MOVEMENT LATERAL	NORTH RAIL MOVEMENT LONGTDL	TEMP °F	SOUTH RAIL MOVEMENT LATERAL	SOUTH RAIL MOVEMENT LONGTDL	NORTH RAIL MOVEMENT LATERAL	NORTH RAIL MOVEMENT LONGTDL	TEMP °F	SOUTH RAIL MOVEMENT LATERAL	SOUTH RAIL MOVEMENT LONGTDL	NORTH RAIL MOVEMENT LATERAL	NORTH RAIL MOVEMENT LONGTDL	TEMP °F	SOUTH RAIL MOVEMENT LATERAL	SOUTH RAIL MOVEMENT LONGTDL	NORTH RAIL MOVEMENT LATERAL	NORTH RAIL MOVEMENT LONGTDL	TEMP °F	SOUTH RAIL MOVEMENT LATERAL	SOUTH RAIL MOVEMENT LONGTDL	NORTH RAIL MOVEMENT LATERAL	NORTH RAIL MOVEMENT LONGTDL	OPEN JOINTS SOUTH RAIL	OPEN JOINTS NORTH RAIL	
				base 8½		base 8½			base 8½		base 8½			base 8½	base 0	base 8½	base 0		base 8½		base 7			base 7½		base 7½			base 8	base 0	base 10	base 0		base 7		base 8½			base 7½		base 8		W end	E end	W end	E end	
DEC. 1 1937			51°	0	0	0	0	56°	0	0	0	0						59°	0	0	0	0	65°	0	0	0	0						63°	0	0	0	0	61°	0	0	0	0			
DEC 8 1937	2:55 P	CLOUDY	39°	1/16S	5/16E	1/8N	5/16E	39°	0	5/16E	1/4S	3/8E						39°	0	1/4E	1/8N	5/16E	39°	1/16S	1/8E	1/16N	1/4E						39°	0	0	0	0	38°	0	0	1/8N	0	3/8		1¼	
DEC 20 1937	8:30 A	CLEAR	48°	0	1/8E	0	1/4E	48°	0	1/16E	0	3/16E						48°	0	1/8W	0	3/16E	48°	0	5/16W	0	1/16E						47°	0	3/4W	0	1/4W	47°	0	1/2W	0	5/16W	3/8E	3/4	9/16	1/2
DEC 29 1937	3:45 P	CLEAR	57°	0	1/2W	1/16N	3/8W	57°	1/16N	3/8W	1/16N	3/16W						57°	0	3/8W	0	3/16W	57°	0	3/16W	0	3/16E						58°	0	1/8E	0	1/4E	58°	0	3/16E	0	1/4E	1/8	3/8	1/2	1/2
JAN 4 1938	10:45 A	CLEAR	56°	0	3/16W	1/16N	3/32E	56°	0	1/8W	1/16N	1/8E						56°	0	1/4W	0	0	56°	0	1/4W	0	1/16W						56°	1/16N	7/16W	1/16S	1/16W	56°	0	3/8W	1/32S	1/16W	1/4	1/2	1/16	1/2
JAN 13 1938	3:15 A	CLEAR	34°	1/16N	3/16E	0	1/16E	34°	0	0	0	3/16E						34°	0	1/4W	0	7/16E	34°	0	3/8W	0	7/8W						34°	1/8N	5/8W	0	3/4W	34°	0	3/4W	1/16S	5/8W	3/8	13/16	3/4	1/2
JAN 21 1938	3:30 P	CLOUDY	70°	1/16N	1/2W	0	5/8W	70°	0	1/8W	0	7/16W						70°	0	9/16W	0	3/8W	70°	0	7/16W	0	3/16W						70°	1/16N	0	1/16S	3/16E	70°	0	1/8E	0	1/4E	1/8	1/2	5/16	1/16
JAN 26 1938	6:45 A	CLEAR	22°	0	5/16E	0	9/16E	22°	0	3/16E	0	1/4E						22°	0	0	0	3/8E	22°	1/16N	1/2W	0	1/16E						22°	1/16N	1/2W	1/16	1/4W	22°	0	3/4W	0	5/8W	1/16	11/16	5/8	1/2
FEB 9 1938	3:15 P	CLOUDY	78°	0	3/4W	0	7/8W	78°	0	5/8W	0	9/16W						78°	0	7/16W	0	3/16E	78°	0	9/16W	0	1/16E						78°	1/16N	1/16E	1/16S	1/2E	78°	0	7/16E	0	9/16E	1/8	1/8	1/16	1/4
FEB 15 1938	3:30 P	CLEAR	82°	0	3/4W	0	5/16W	82°	1/16N	3/4W	1/16N	1/16W	82°	0	3/4W	0	9/16W	82°	0	3/4W	0	7/16W	82°	0	1/4W	0	3/4W	82°	0	1/8W	0	3/16W	82°	1/16N	0	1/16S	3/8E	82°	0	1/8E	0	1/2E	1/16	1/4	0	1/4	
FEB 25 1938	11:30 A	CLOUDY	43°	0	1/2W	1/16N	0	43°	0	3/8W	0	1/16E	43°	0	1/2W	0	5/16E	43°	0	1/2W	0	1/8E	43°	0	9/16W	0	1/16E	43°	1/16N	3/8W	1/16N	3/16W	43°	1/8N	1/16W	1/16S	1/8W	43°	0	3/4W	0	5/16W	1/8	5/8	1/2	
MAR 4 1938	11:00 A	CLOUDY	66°	0	3/4W	1/16N	1/2W	66°	0	5/8W	0	3/16E	66°	0	5/8W	0	3/16E	66°	0	5/8W	0	1/8E	66°	0	9/16W	0	5/16E	66°	1/16N	3/16W	0	3/16E	66°	1/8N	5/16W	1/16S	1/2E	66°	0	1/4W	0	1/2E	1/8	1/4	1/8	3/8	
MAR 11 1938	1:15 P	FAIR	75°	0	1/4W	0	5/16W	75°	0	3/4W	0	5/8W	75°	0	7/8W	0	5/16W	75°	0	7/8W	0	5/16W	75°	0	1/16W	0	0	75°	1/16N	1/4W	0	1/16W	75°	1/16N	1/8W	1/16S	7/16E	75°	0	0	0	5/8E	1/16	1/4	1/16	1/2	
MAR 24 1938	3:15 P	FAIR	86°	0	1 1/16W	1/16N	1/16W	86°	0	1 1/16W	0	1/8W	86°	0	1"W	0	9/16W	86°	0	1 5/16W	0	3/8W	86°	0	3/16W	0	0	86°	0	1/4"W	0	1/8E	86°	1/16N	1/4W	1/16S	1 1/16E	86°	0	0	0	3/16E	1/8	3/16	1/16	1/16	Contraction anchors removed and reapplied at transition anchors 8:20 A.M. March 23, 1938.
APR 5 1938	6:15 A	FAIR	84°	0	1 3/8W	1/16N	1 5/16W	84°	0	1 1/8W	0	5/8W	84°	1/16S	1 3/8W	0	1/4W	84°	0	1"W	1/16S	1/8W	84°	0	1/8W	0	1/8E	84°	0	1/16W	0	1/8E	84°	1/16N	3/8W	1/16S	1/2E	84°	0	5/16W	0	7/16E	1/8	3/16	1/16	1/16	
APR 15 1938	7:15 P	FAIR	98°	1/16N	1 7/16W	1/16N	1 7/16W	98°	0	1 3/4W	0	3/4W	98°	0	1 1/4W	0	7/16W	98°	0	1 1/8W	0	5/16W	98°	0	1/8W	0	1/16E	98°	0	1/4"W	0	1/16E	98°	1/16N	1/8W	1/8S	5/8E	98°	0	0	0	3/4E	1/16	0	1/16	1/16	
APR 25 1938	11:30 A	FAIR	97°	1/16N	1 1/2W	0	1/8W	97°	0	1 3/4W	0	1 3/16W	97°	0	1 5/16W	0	1/2W	97°	0	1/8W	0	1/16W	97°	0	3/8W	0	1/16E	97°	0	3/8W	0	1/16E	97°	1/16N	1/4W	1/16S	9/16E	97°	0	5/16W	0	11/16E	0	0	1/16	1/16	
MAY 10 1938	10:45 A	FAIR	91°	1/16N	1 5/16W	0	1/4W	89°	0	1 3/16W	0	3/4W	87°	0	1 3/8W	0	5/16W	87°	0	1 1/4W	1/16S	1/16W	82°	0	1 3/16W	0	5/16E	81°	0	1 1/16W	0	1/2E	81°	1/16N	1 3/16W	1/16S	1 3/16E	81°	0	1 3/16W	0	3/4E	1/8	0	1/16	1/16	At 8:25 P.M. Open Joint at E. End of South Rail Found open 0 3/4". Two (2) Bolts were put on the East end connecting 39' rails
JUNE 1 1938	1:45 P	CLOUDY	84°	1/16N	1 3/4W	0	1 5/16W	84°	0	1 7/16W	0	7/16W	86°	0	1 7/16W	0	7/16W	86°	0	1"W	0	1/4E	86°	1/16N	1/16W	0	7/16E	86°	1/16N	1/2W	1/16S	7/8E	86°	0	1/8W	0	1"E	0	0	0	1/16E	0		
JUNE 3 1938	2:30 P	FAIR	107°	1/16N	1 15/16W	1/16N	1 3/8W	107°	0	1 7/8W	0	3/8W	107°	0	1 3/8W	0	3/8W	107°	0	1 1/16W	0	1/8W	107°	0	1/16W	0	7/16E	107°	0	1/16W	0	9/16E	107°	0	3/16E	0	1 1/16E	107°	0	3/16E	0	1 1/16E	1/16	1/16	1/16	0	At 3:55 P.M. May 24, 1938 - 48" welded Angle Bar was applied to E. End of South Rail with 6 Bolts
JULY 3 1938	11:30 A	CLOUDY	112°	0	2"W	1/16N	1 9/16W	112°	0	1 7/8W	0	1 5/16W	112°	1/16S	1 1/2W	0	7/16W	112°	0	1 3/16W	1/16S	3/16W	112°	0	1/8W	0	1/2E	112°	0	3/16W	0	13/16E	112°	0	1/8S	1 1/4E	112°	0	3/16E	0	15/16E	1/16	0	1/16	0	
JULY 18 1938	1:45 P	FAIR	114°	1/16N	1 7/8W	0	1 9/16W	114°	0	1 9/8W	0	1"W	114°	1/16S	1 7/8W	1/16S	1 3/8W	114°	0	1 5/8W	0	1/2W	114°	0	5/8W	0	1/2E	114°	0	0	0	1/16E	114°	0	1/8S	1 3/4E	114°	0	5/16E	0	1 3/8E	1/16	1/16	1/16	0	
AUG 3 1938	10:45 A	FAIR	100°	1/16N	1 13/16W	1/16N	1 2W	100°	0	1 5/8W	0	1 1/16W	100°	1/16S	1 3/8W	0	1/16W	100°	1/16S	1 1/16W	1/16S	1/8W	100°	0	5/8W	0	9/16E	100°	0	1/16E	0	1 3/16E	100°	0	3/16E	1/8S	1 3/16E	100°	0	5/16E	0	1 5/16E	1/16	1/16	1/16	0	
AUG 3 1938	1:30 P	FAIR	108°	1/16N	1 15/16W	1/16N	1 2W	108°	0	1 9/16W	0	1 1/16W	108°	1/16S	1 3/8W	0	1/16W	108°	1/16S	1 1/16W	1/16S	1/8W	108°	0	5/8W	0	9/16E	108°	0	1/16E	0	1 3/16E	108°	0	1/8E	1/8S	1 1/4E	108°	0	1/16E	0	1 3/8E	1/16	1/16	1/16	0	
AUG 26 1938	11:30 A	FAIR	116°	1/16N	2 1/16W	1/16N	1 9/16W	116°	0	1 3/8W	1/16N	1"W	116°	1/16S	1 1/16W	1/16S	1/16W	116°	1/16S	1 1/16W	1/16S	1/16E	116°	0	1/16W	1/16S	1 3/16E	116°	0	0	0	1"E	116°	0	1/8E	1/8S	1 1/16E	116°	0	1/16E	0	1 1/4E	1/16	0	1/16	0	
OCT 8 1938	11:30 A	FAIR	85°	0	2 1/16W	1/16N	1 3/8W	85°	1/16N	1 1/16W	1/16N	1/2W	85°	1/16S	1 3/8W	0	1/4W	84°	1/16S	1 1/16W	1/16S	1/16E	84°	0	1 1/16W	0	9/16E	83°	1/16N	9/16W	0	1/8E	83°	1/16N	1/16W	1/8S	1 3/16E	83°	1/16N	1/4W	1/16S	1 3/8E	1/8	1/16	1/16	1/16	

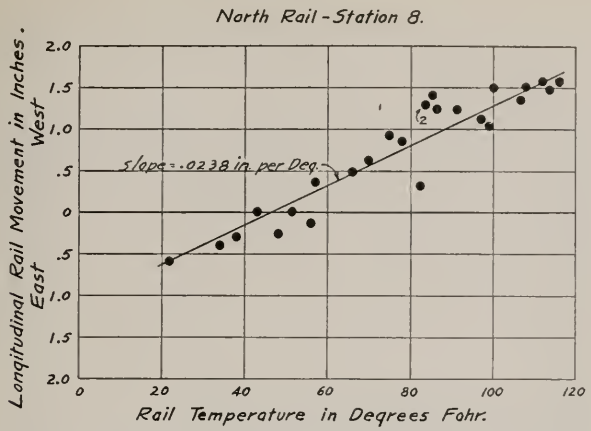


FIG. 6.—Measured Longitudinal Movement Near Ends of Welded Rail at Various Temperatures — October, 1937–October, 1938.

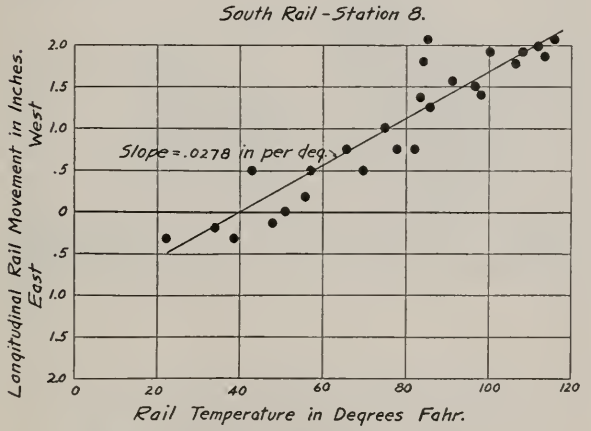


FIG. 7.—Measured Longitudinal Movement Near Ends of Welded Rail at Various Temperatures — October, 1937–October, 1938.

Fig. 3 is a tabulation showing the amount of these movements at various temperatures throughout the winter of 1937–1938 and the summer of 1938. From these data, diagrams (Figs. 4 to 7, inclusive) have been prepared which show in graphical form the measured longitudinal movements at the ends of the welded rail. It will be noted that within the range of 22 deg. to 116 deg. rail temperature variation, the total end movement was as follows:

East end north rail—Station 1—2.1 in.
East end south rail—Station 1—1.25 in.
West end north rail—Station 8—2.1 in.
West end south rail—Station 8—2.35 in.

The average rate of end movement is approximately 0.02 in. per degree temperature change which compares with 0.01 in. per degree on the B. & L. E. installation (AREA Proceedings, Vol. 39, p. 870).

Strain measurements were also taken at various rail temperatures to determine the amount of temperature stresses that were developd in the rail, from which information could be obtained on the holding power of the fastenings. The amount of temperature strain was determined by measuring with a strain gage the distance between two gage points set approximately 20 in. apart in the web of the rail at numerous locations along the track. Fig. 8 shows the manner of taking these measurements. These measurements were compared with measurements between two gage points set 20 in. apart in the web of a short piece of rail which was free to expand or contract without restraint. This reference rail was maintained at approximately the same temperature as the track rail.

Fig. 8.—Measuring Rail Strain with 20-in. Strain Gage.

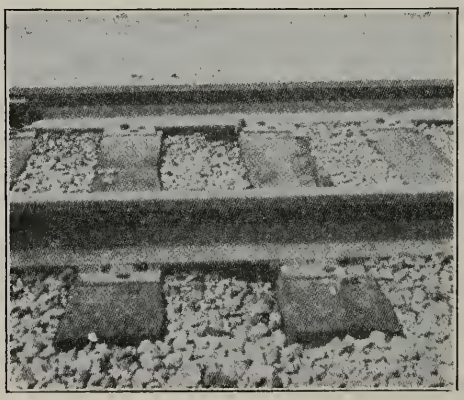


Fig. 9.—Rail Anchors Resisting Expansion Near West Ends of Welded Rail in Summer. Tie Has Been Moved Somewhat in Ballast.

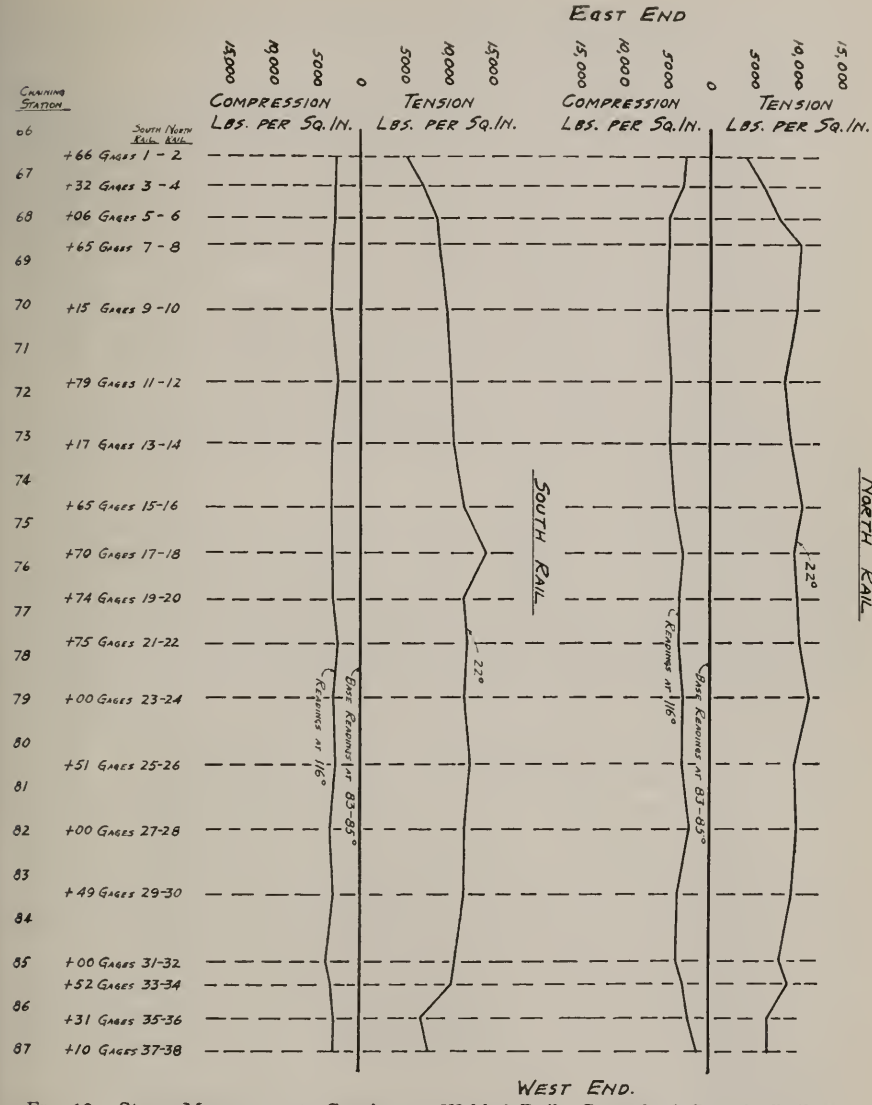


FIG. 10.—Stress Measurements Continuous Welded Rail—Central of Georgia Railway Near Lovejoy, Ga.

Unfortunately, strain measurements were not obtained before the rail was welded and placed in track, which would have served as a base for measurement and permitted exact determination of the amount of tension and compression respectively. However, a series of measurements were taken when the rail was at a temperature of 83 deg.—85 deg., which approximated the laying temperature. Strain-gage measurements taken with rail temperatures of 22 deg. and 116 deg. were compared with these base readings, and the results are shown in diagrammatic form on the accompanying chart (Fig. 10). The total changes

in stress between the 22 deg. and 116 deg. temperatures are considered accurate, but as previously stated the apportionment of this stress change between tension and compression must be considered as an approximation.

Observation of Fig. 10 will show that the end restraint accounts for over one-half of the total restraint developed. Most of the end restraint was due to joint restraint. but not all because there were from 8 to 13 anchors between the point of measurement of end movement and the actual end of the welded rail. The tie restraint was developed principally within the location of the rail anchors. It does not appear that the double-shouldered tie plates and cut spikes developed much restraint, but apparently the rail anchors spaced six to the rail length (in effect 12 to the rail length, since they were relocated in summer and winter) were effective.

The maximum temperature stress at the center portion of the welded rail approximates 15,000 lb. per sq. in. For conditions of complete restraint, a temperature stress of 116-22 $\times$ 195 = 18,300 would have been developed (See AREA Proceedings—Vol. 38, Page 493). The combined joint, tie-plate, cut-spike, and rail-anchor restraint was not sufficient, therefore, to completely restrain the center portion of the welded rail.

On pages 499–500 of the ASCE Transactions, Vol. 193, 1938, Dr. A. N. Talbot makes the following statement with reference to measurements made on the B. & L. E. installation of welded rail with GEO type fastenings:

"The length of the end portions which give anchorage to the intermediate portion, and the stress set up in the intermediate portion correspond to an average anchorage or restraint of about 600 lb. per tie per rail in each direction for the temperature of 113 deg. F. and 16 deg. F. as counted above and below a laying temperature of 63 deg. F. If the anchorage length remains fairly constant for temperatures above or below the aforementioned range as is indicated to be the case by the data of the various tests, the corresponding anchorage force would be proportionally greater than 600 lb."

In order to compare with this value the restraint in the Central of Georgia welded installation with cut-spike fastenings, double-shouldered tie plates, and rail anchors, analysis of the stress measurement diagram (Fig. 10) indicates that within the range of temperature, 22 deg. to 116 deg., the ties on which rail anchors pressed developed an average total restraint of 1,700 lb. per tie per rail in both directions, or, if it be assumed that the resistance to expansion movement was equal to that in contraction movement, the restraint developed averaged 850 lb. per tie per rail in each direction of movement. Similarly, the tie restraint developed at ties with double-shouldered tie plates and cut-spike rail fastenings only is indicated by the stress measurements to have averaged 40 lb. per tie per rail in both directions, and, if it be again assumed that the resistance to expansion and contraction movements were equal, the restraint averaged 20 lb. per tie per rail in each direction of movement. This is approximately twice the resistance to movement that would be expected from the frictional resistance of the rail weight to sliding over the tie plate.

The rail end movements as determined from the permanent monuments and calculated from the measured strains present an interesting comparison and check on the accuracy of the measurements.

South Rail

Length of rail—2,044 feet.

For 94 deg. temperature change the rail should have changed its length:

2044 ft. $\times$ 12 in. $\times$ 94 deg. $\times$ 0.0000065 = 14.99 in., in which .0000065 is taken as the coefficient of expansion of rail steel.

Average change in temperature stress as measured in rail = 14,100 lb. per sq. in.

The amount of end movement restrained corresponding to this average stress is

$$\frac{14{,}100 \times 2{,}044 \times 12}{30{,}000{,}000} = 11.53 \text{ in.}$$

The total measured end movement between the 22 deg. and 116 deg. series of readings would be expected to be 14.99—11.53 = 3.46 in.

Actually it was found by measurement (See Fig. 3) to be

= 3.44 in.

North Rail

The amount of end movement of this rail, if free of restraint, would also have been 14.99 in.

The average change in temperature stress as measured in the rail was 13,190 lb. per sq. in.

The amount of end movement restrained corresponding to this stress is

$$\frac{13{,}190 \times 2{,}044 \times 12}{30{,}000{,}000} = 10.78 \text{ in.}$$

The total measured end movement between the 22 deg. and 116 deg. series of readings would be expected to be 14.99—10.78 = 4.21 in. Actually it was found by measurement to be (Fig. 3) 4.25 in.

The conformity of the above end movements as determined from the rail movements and strain gage readings is closer than would be expected, considering the accuracy with which the coefficient of expansion of the rail was known. The coefficient of expansion of rail steel has been considered to be 0.00000632 (AREA Proceedings, Vol. 38, Page 677); German engineers use a value of 0.00000638; and Trautwine gives a value of 0.0000065, which value has been quite generally used in providing expansion allowance for rail laying. However, it is considered that the foregoing conformity establishes the reliability of the strain measurments.

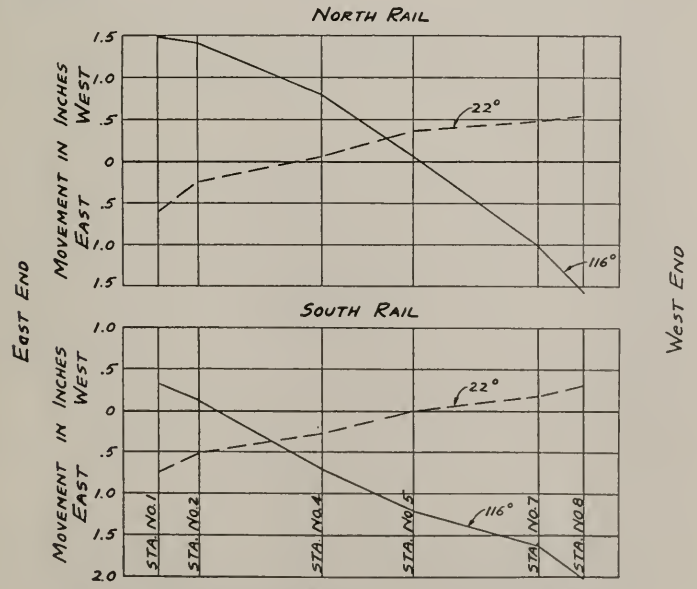


FIG. 11.—Longitudinal Movement of Continuous Welded Rail—Central of Georgia Railway Near Lovejoy, Ga.

Attention is directed to the fact that the lateral measurements in Fig. 3 show no appreciable lateral movement in any portion of the track throughout the test period.

In Fig. 11 the measured longitudinal rail movements at the extremes of 22 deg. and 116 deg. are presented in graphical form. This diagram shows that some rail movement has occurred throughout the test section.

Delaware & Hudson and Bessemer & Lake Erie Installations

Complete information on these two installations appears in the "Discussion on Stresses in Railroad Track" by Dr. A. N. Talbot (AREA Proceedings, Vol. 39, p. 867).

Mr. P. O. Ferris, acting engineer maintenance of way, The Delaware & Hudson Railroad, has very kindly furnished the following interesting and valuable information relative to the experience with welded rail installations secured with M. & L. type fastenings on that road.

Referring to the list of locations where rail is installed, we have had no trouble with the welded rail, except at Port Henry and Harpursville.

At Port Henry, one stretch of rail, 720 ft. in length, was laid in the early part of June, 1937, on a rainy day when the rail temperature was about 57 deg. F., and on the next hot day the rail went out of line about two inches on a 5-deg. curve. At the time this occurred the track was lined to permit traffic to move, and no interference to trains was experienced. At the first opportunity, when the weather was hot (around 90 deg. F.), the rail in this particular stretch was loosened and allowed to run out, then reclipped. Since that time, no trouble from buckling or from any other source has been experienced on any of the welded stretches at Port Henry.

At Harpursville, trouble of a similar nature was experienced in April, May, and June of 1938. This rail was laid in August, 1937, in lengths of 740 ft. at an average rail temperature of 90 deg. F.; these 740-ft. lengths were then joined together in track by closure welds, leaving only open joints at signals and turnouts. Due to traffic conditions, it was found best to do this closure welding at night when it was possible to obtain the tracks for more time between trains than in the daytime. This closure welding was done during September, 1937, and the rail temperature ranged from 30 deg. to 70 deg. F., with an average temperature of about 45 deg. F. Due to the fact that the rail temperature at the time of the closure welding was so much lower than the temperature was when the rail was laid, it was necessary to insert a longer piece of rail when making the closure welds. In all, over the five-mile stretch of rail at this point, there were 42 in. of rail added in both the east rail and the west rail.

When the closure welding was done, it was realized that this addition of rail would have an effect on the condition of the track in hot weather and plans were made to loosen the welded rail between insulated joints and/or turnouts and allow it to run out before re-clipping. This, of course, was not necessary until the spring of 1938. However, due to a combination of circumstances this was not done until after trouble from buckling had been experienced. These circumstances were the experiencing of several unseasonably hot days in April, and a shortage of labor due to reduction of forces caused by economic conditions. The buckling experienced was at various points over about four miles of the welded rail at Harpursville and these were the locations which went out of line from 2 in. to 4½ in. in April; three locations of from 1 in. to 2 in. in May; and four locations when the rail went out of line only enough to make it appear like poor line on June 24.

During the period from April through June, the welded rail was loosened and allowed to run out, then re-clipped, this work being done on hot days. A total of 13¼ in. in the east rail and 13¾ in. in the west rail was thus removed to compensate for the effect of that added during the closure welding.

In developing the use of continuous welded rail, we have established certain rules for its installation and maintenance: From experience we established that continuous welded rail should not be laid at a temperature lower than 70 deg. F., preferably between 80 deg. and 90 deg. F. or, if laid at a temperature lower than this, it should be loosened at the first opportunity when the temperature is as specified above, allowed to run out, and then reclipped.

Data on Welded Rail Installation—Delaware & Hudson Railroad

Location	No. of Welds		Lin. Feet Welded Rail		Type of Ballast	Year	Track	Weight on Rail Heaviest Pr. Drivers		Max. Speed		Traffic Density—Trains per day		Gross Tonnage Per Mile Per Year	
	Thermit	Flash	Thermit	Flash				Freight	Pass.	Frt.	Pass.	Frt.	Pass.	Frt.	Pass.
Albany, N. Y.	316		12,075		Crushed stone	1933	N. B.	72,000	67,700	20	20	4	22	6,262,729	611,225
							S. B.	72,000	67,700	20	20	4	18	5,378,325	611,225
Mechanicville, N. Y.	254		10,071		Crushed stone	1934	N. B.	72,000	67,700	15	15	8.3	8	1,427,938	1,780,286
							S. B.	72,000	67,700	15	15	9.7	8	1,287,420	1,780,286
Schenectady, N. Y.	551	70	18,218	5,356	Crushed stone	1935	S. B.	78,300		30		7.6		9,583,777	
Windsor, N. Y.	281		19,286		Crushed stone	1935	N. B.	67,500		30		6.4		10,739,654	
							S. B.	67,500		30		6.4		6,288,241	
Cohoes, N. Y.	74		3,035		Crushed stone	1936	N. B.	72,000	67,700	10	10	2.8	8	1,555,636	1,780,286
							S. B.	72,000	67,700	10	10	2.8	8	1,444,346	1,780,286
Comstock, N. Y.	409		16,044		Crushed stone	1936	N. B.	72,000	67,700	30	75	3.9	6	4,352,548	1,365,373
							S. B.	72,000	67,700	30	75	5.3	6	3,598,733	1,365,373
Schenectady, N. Y.	1,559	874	62,010	34,900	Crushed stone	1937	S. B.	78,300		30		7.6		9,583,777	
Port Henry, N. Y.	98*	1,987		82,527	Ore Sand	1937	Single	67,300	67,700	30	35–65	8.2	10	6,514,703	2,427,266
Harpursville & Bainbridge	112*	1,655		72,491	Cinders	1937	Single	72,000	67,700	30	60	10.9	4	11,043,439	**816,970
							N. B.	72,000	67,700	30	60	6.5	2	6,561,253	†408,485
Watervliet, N. Y.	53*	1,622		66,487	Stone and Cinders	1937	N. B.	72,000	67,700	30	65	7.9	6	1,555,636	1,780,286
							S. B.	72,000	67,700	30	65	7.9	4	1,444,364	1,780,286
Total	3,707	6,208	140,740	261,761											

*Closure welds only **Harpursville †Bainbridge

To take care of such circumstances as arose at Harpursville where rail was added or removed from a length of welded rail, a table was prepared,* showing the effect of this addition or removal of rail on the "No Stress Temperature". The term "No Stress Temperature" was coined to give a definite reference or working point in connection with installations of welded rail, and is the temperature below which the rail would be in tension and above which the rail would be in compression. The simple example of the "No Stress Temperature" is the temperature at which a particular stretch of welded rail is laid.

Applying the effect of the addition of rail, during the closure welding at Harpursville on the "No Stress Temperature", we found that there was a lowering of about 26 deg. F., or from the 90-deg. F. average laying temperature to 64 deg. F.; then again obtaining the effect of the removal of rail in the spring of 1938 by loosening the rail and allowing it to run out, the "No Stress Temperature" was raised by about 9.5 deg. F., which brought it up to 73.5 deg. F., which is within the limits where no buckling is experienced. This is also borne out by the fact that during July and August of 1938 we experienced equal and higher temperatures than those experienced when the rail went out of line during April, May, and June.

The only other difficulty experienced was the breaking of the bolts in eight angle-bar joints at the ends of welded rail stretches during last winter. These breaks were, in each case, due to improper drilling of the rail which caused the strain to come entirely on one bolt, and this condition has been corrected by carefully re-drilling new holes. It might be noted here that our standard angle bar is an 18-in. four-bolt type and, should more trouble of this nature be experienced, the use of a longer angle bar with six bolts would, undoubtedly, overcome it.

In conclusion, I would say that what trouble we have had with the welded rail would fall into the category of useful data since we have been able to analyze and rectify the conditions causing the difficulty and also that, compared with the total mileage of continuous welded rail which we have, the stretches where this trouble has occurred are small.

Mr. F. R. Layng, chief engineer of the Bessemer & Lake Erie Railroad, has very kindly furnished the following information with reference to the experience to date with the welded rail installation secured with GEO type fastenings, near River Valley:

Extract from letter dated July 3, 1937:

Just previous to the last measurements taken June 25, we found it necessary to slightly surface and line the track through the area covered by the monuments A_1 to A_6, inclusive. This is on a fill just adjacent to an overhead bridge. During the last month or two, this fill had settled slightly so that we thought it advisable to resurface and line the track.

As a whole, the installation has given us no trouble whatever. Aside from the surfacing and lining mentioned above, no work has been done on the track, except in March, 1936, we had a slight settlement on the 5 deg. 43 min. curve, which is on a very high fill. This settlement was caused by excessively wet weather and we had no difficulty whatever in surfacing the track and bringing it back to line. Since that time, no work has been necessary at the point in question. Where this work was necessary is not in an area where we have permanent monuments.

The gross tonnage over this welded rail is now running at approximately 3,000,000 tons per month. Our estimate as to the total tonnage over the welded rail since it was installed is slightly over 20,000,000 tons, up to May 31, 1937.

We have had no broken welds, and the area on the top of the head of the rail in the vicinity of the weld shows no breaking down or cupping. At a number of the welds and on the gage side of the rail, there is some evidence of porous metal. As yet, this has had no effect whatever on the running surface of the rail and we do not know whether it will be progressive and later give evidence of weakness. We can only say that up to the present time these spots have not enlarged nor in any way affected the running surface of the rail.

*Note—(Copy of this table is not included because of the space required. The effect in degrees on "No Stress" temperature of adding or removing rail in welded rail stretches as given therein may be calculated by dividing the length in inches of the piece of rail added or removed by 0.0000065 times the length of the welded rail stretch effected in inches.)

Extract from letter dated August 16, 1937:

Recently, we ran a 72-hour observation test at the south end of the welded rail stretch, making readings every hour at three of the stations, which are marked with permanent monuments. The purpose of this was to get a continuous record of air temperature, internal rail temperature, and rail movement, covering a fairly wide range of temperature. We had a range of about 50 deg. F., and the maximum range of movement at the south station AA was 5/32 of an inch. It is also of interest that at the other two stations, A_2A_2 and A_6A_6, the range was only 2/32 of an inch.

For your further information, wish to advise that there is no substantial change in the condition of the rail or the track, since you last saw it. The welds are standing up fine, notwithstanding the fact that we are putting the heaviest tonnage in the history of the road over this stretch. We have had to do no maintenance work, other than a little surfacing adjacent to the overhead bridge at the south end of the welded rail, this due to a slight settlement of the subgrade, which is on a fill approaching the overhead. The track as a whole has remained in first class line and surface.

Extract from letter dated September 19, 1938:

My last report to you on this installation was July 3, 1937. Since that time we have had no difficulty whatever as to buckling, excessive movement, failure or slippage through any of the fastenings.

On August 25, 1937, our track supervisor observed a broken rail joint, No. 246 on the east side of the track, low side of the 5 deg. 43 min. curve. A section of rail 17 ft. 6 in. long was cut out, a new section put in and temporarily bolted with angle bars. Following this, equipment was secured from Metal and Thermit Corporation and the temporary section put in was removed and new 39-ft. section was placed. The work was done under traffic, one weld being made each day as trains permitted. GEO clips and bolts were removed for two rail lengths each side of the joint so that the rail ends could be made straight through the clamp. The rail ends were cleaned and the web and base undercut in the usual manner. The rail was pre-heated and after the joint was poured and the grinding done the joint was finished with fine grinding. A one-inch steel insertion piece was required at the south end of the weld. This insertion piece was cut from 131-lb. RE rail and included the head of the rail and ½ in. of the web. The moulds were somewhat different from those used in 1935 when the track was originally welded. The new design of mould prevents any blow-outs under the head of the rail while the weld is being made.

The section of rail cut out was put in the laboratory and the reports show—

1. That due to the blowing out of some of the Thermit metal when originally poured there was a half-moon shaped portion of the metal burned, reducing a section of the web to 74 percent of the original. This introduced a structural weakness at this point. This area was a crescent-shaped groove and from 1¼ to 1½ in. in length.

2. Decarburization of the metal due to overheating. This overheating took place at the time of pre-heating when the weld was originally cast, this being preliminary to pouring the Thermit metal into the mould.

Since our work was done, the Metal and Thermit Corporation has developed better methods of pre-heating.

Careful examination was made of the other welds in the installation at the time this break took place and this inspection showed that Joint No. 99 had a crack in the vicinity of the weld through the web, so we decided to cut this joint out also, which was done at the same time the weld was made on Joint No. 246.

Nothing else of interest has been observed that we feel would be necessary to report.

Summary

The subcommittee has inspected and reported upon three installations of welded rail, each secured with a different type of fastening. It is the opinion of the subcommittee that these installations have not been in service sufficiently long to justify approval or recommendation of the particular fastenings used. Based upon its observation and

study of information available to date, the following comments are offered. It should be kept in mind that further experience with welded rail may make revision of these comments desirable.

1. The type of fastening used to secure the rail, tie plate, and tie assembly should develop a resistance to longitudinal movement of the rail relative to the tie of at least 600 lb. per tie per rail, and a higher resistance is desirable, if the full capacity of tie restraining force is to be developed.

2. Double-shouldered tie plates with two cut-spike rail fastenings on tangent and three cut-spike rail fastenings on curves, and with two cut-spike hold-down plate fastenings in addition, offer sufficient resistance to lateral movement of the rail relative to the tie, and perhaps offer lateral resistance in excess of what may be required.

3. The cut-spike fastenings described in (2) offer sufficient resistance to the rail being lifted out of its seat in the tie plate by "buckling" forces, provided the ties are in good condition and the spike holes in the ties are not so worn or decayed as to have appreciably lost their holding power.

4. Best results have been obtained when continuous welded rail was laid and secured in the fastenings at rail temperatures between 70 deg. and 90 deg. F. If necessary to lay welded rail at lower or higher rail temperatures than this range, the joints and fastenings should be loosened at the first opportunity when the rail temperature is within this range, and a short length of rail inserted or removed as required. The installation of two joints with an intervening length of rail between abutting stretches of continuous welded rail will facilitate this operation, and will provide a convenient means of emergency adjustment in the event of rail failure or track buckling.

Design of Screw Spike to be Used as an Independent Tie Plate Fastening

As a basis for a study of this subject, information appearing in past issues of the AREA Proceedings relative to the design of the present standard screw-spike rail fastening was reviewed.* Based upon these data and other valuable information, the following principles may be established with respect to the design of the screw-spike tie plate fastening:

1. The diameter of the spike under the head will determine its resistance to vertical and lateral forces; the larger the diameter of the spike, the larger its resisting power. The resistance to vertical pull of the 7/8-in. diameter screw spike may be taken at approximately 10,000 lb. in hardwood ties and 7,500 lb. in softwood ties. Data on the lateral resistance are not available.

2. The diameter of the shank of the spike is determined largely by the depth of the thread which it is possible to roll. A thread depth of 5/32-in. is about the maximum that can be provided.

3. The greater the depth of the thread, the greater the holding power of the threaded portion in the tie. Experiments have indicated that the shape of the thread itself is not of appreciable importance in developing holding resistance.

4. The most satisfactory pitch of the thread must be determined by experimentation. If the pitch of the thread is too small, the wood fibers will be unduly damaged in the insertion of the spike. If the pitch is too large, the full possibility of holding power will not be developed and the torque required to insert the spike will be unduly large. Experiments have shown that the pitch should be approximately 1/2 in.

5. The length of the spike under the head should be such that it will not extend through the tie, and the length of the unthreaded portion of the neck under the head

* In order to avoid confusion in this report the term screw-spike rail fastening will be used to refer to a screw spike used to secure the rail to the tie and the term screw-spike plate fastening will refer to a screw spike used to secure the tie plate to the tie independently of the rail fastening.

should be sufficiently long to extend through the tie plate into the upper fibers of the tie.

6. The spike should be pointed to permit convenient starting in the bored hole.

7. The bearing area of the spike head should be sufficient to keep the bearing pressure within permissible limits with allowance for corrosion.

8. The area of that portion of the head which is engaged by the wrench should be somewhat in excess of the neck area. The sides of this portion of the head should be sloped so that, when corrosion occurs, the wrench may be slipped farther down to insure a satisfactory grip. A stamped letter or raised portion should be provided on the top of the head to discourage striking the spike with a mall. The head portion which is engaged by the wrench should be shaped to afford the best grip with a wrench throughout various stages of corrosion and a rectangular shape is to be preferred on this account.

Before recommending a design for a screw-spike tie plate fastening, it is desired to give further study to the actual load requirements which must be met in service, namely, the magnitude of vertical and lateral forces to which the screw spike plate fastening will be subjected. When this is determined, it will be possible to recommend a design which will be adequate for these requirements.

The committee submits this report as information and recommends that the subject be continued.

Appendix C

(3) PLANS AND SPECIFICATIONS FOR TRACK TOOLS

W. L. Roller, Chairman, Subcommittee; W. H. B. Bevan, E. W. Caruthers, H. R. Clarke, L. W. Deslauriers, J. A. Ellis, F. S. Hales, E. T. Howson, F. J. Jerome, E. E. Martin, J. B. Myers, C. J. Rist, I. H. Schram, F. S. Schwinn, J. F. Shaffer, G. M. Strachan, J. N. Todd.

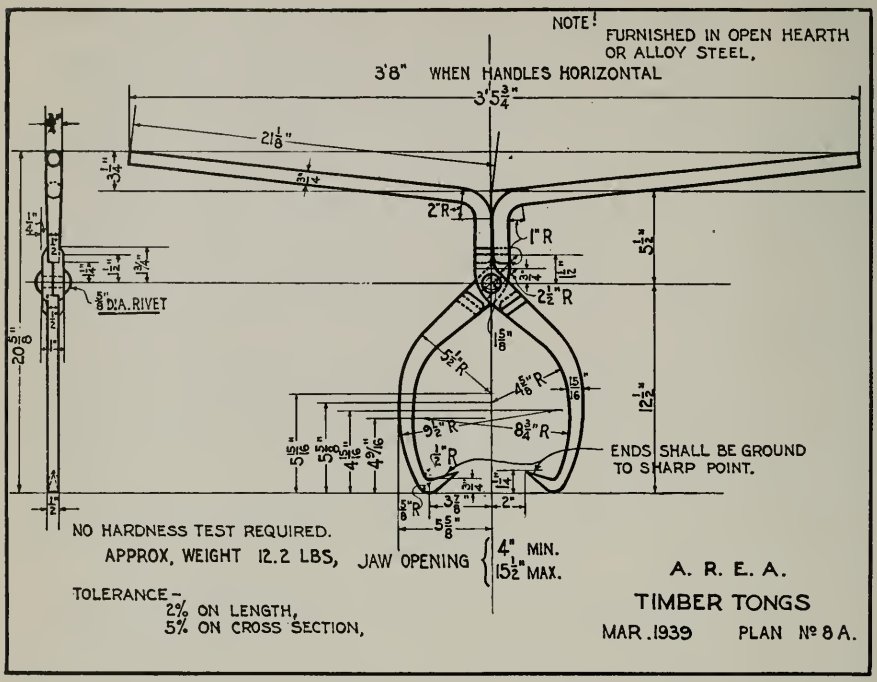
In the Manual for 1936, page 5–58, is shown plan No. 8—Timber Tongs. The committee is now offering for study and comparison a new and lighter design of timber tongs. This new design of tongs offers some improved features in the way of safety and workability which it is felt will be attractive. Attention is called to length of handles, weight and trimness of design of the proposed tongs. This plan is offered as an alternate design and for information under plan No. 8–A, with the understanding that later on it will be offered for adoption as recommended practice as a substitute for the present design, and printed in the Manual.

In the 1936 Manual, page 5–48, under Specifications—Inspection and Physical Tests, Item 14—Timber Tongs, plan No. 8 is shown "No Special Test Required". The committee wishes to offer the following physical test for information and to invite comments and criticisms from the membership:

Physical Test—Timber Tongs, Plans 8 and 8A.

Three pairs of tongs to be tested from each lot of ten dozen or less by suspending a load of 300 lb. to 400 lb. workwise in the tongs with the handles in a horizontal position and supported at a point 2 in. from the end. Deflection with 300 lb. weight shall not exceed 1 inch with no permanent set, and with a 400-lb. weight the deflection shall not exceed 1¼ inches and with a permanent set of not to exceed ⅛ of an inch.

The committee is continuing its study on plans covering Track Level and Elevation Gage, Scythe, Snath, Spot Board and Wood Center Track Gage, as presented to the convention last year for comments. Progress is being made, particularly in regard to the development of an improved Track Level. Comments have been received from a number



of railroad members which have proved very helpful, and the committee solicits further suggestions and criticisms.

The report is offered as information with the recommendation that the subject be continued.

Appendix D

(4) PLANS FOR SWITCHES, FROGS, CROSSINGS, SLIP SWITCHES, ETC., AND TRACK CONSTRUCTION IN PAVED STREETS

E. W. Caruthers, Chairman, Subcommittee; L. L. Adams, W. H. Bettis, C. W. Breed, L. H. Bond, O. U. Cook, E. D. Cowlin, H. Q. Day, L. W. Deslauriers, J. A. Ellis, O. F. Harting, N. M. Hench, F. W. Hillman, A. F. Huber, W. G. Hulbert, T. T. Irving, A. A. Johnson, C. T. Jackson, R. E. Miller, W. A. Murray, J. B. Myers, L. I. Martin, F. H. Masters, G. A. Peabody, S. H. Poore, O. C. Rehfuss, J. A. Reed, C. J. Rist, J. R. Scatterday, G. J. Slibeck, C. R. Strattman, G. L. Sitton, J. N. Todd, H. N. West, J. G. Wishart, M. J. T. Zeeman.

Curved Switches

The committee has continued work on the preparation of detail plans covering Curved Switches as shown diagrammatically on Plan No. 920 covering Turnout Data for Curved Switches.

In the preparation of the plan for the 11-Ft. Curved Switch with Uniform Risers, it was found that in order to meet the requirements for locomotives of 12-ft. maximum rigid wheel base with 3 pairs of flanged wheels or 14-ft 6-in. maximum rigid wheel base with 4 pairs of flanged wheels, the gage through the turnout side of the switch must be at least 4 ft. 9 in. for satisfactory operation.

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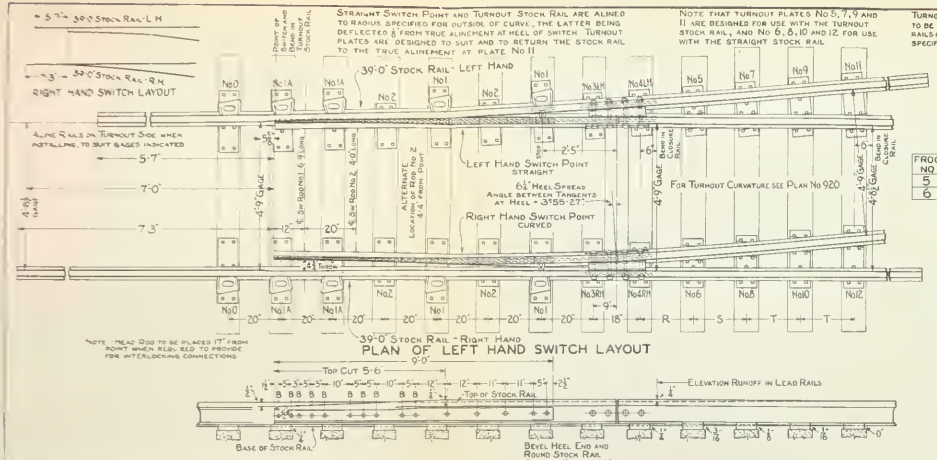
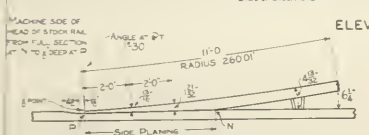
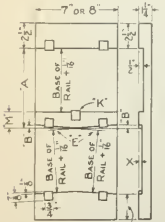

39'-0" Stock Rail - Left Hand
39'-0" Stock Rail - Right Hand
PLAN OF LEFT HAND SWITCH LAYOUT
ELEVATION OF SWITCH POINT
Left Hand Switch Point Straight
Right Hand Switch Point Curved
6½' Heel Spread
Angle between tangents at heel = 3°55'27"
For Turnout Curvature see Plan No 920
Elevation Runoff in Lead Rails
Base of Stock Rail
Bevel Heel End and Round Stock Rail Side per Plan No 140
Straight Switch Point and Turnout Stock Rail are alined to radius specified for outside of curve, the latter being deflected ⅛" from true alinement at heel of switch. Turnout plates are designed to suit and to return the stock rail to the true alinement at plate No 11
Note that turnout plates No 5, 7, 9 and 11 are designed for use with the turnout stock rail, and No 6, 8, 10 and 12, for use with the straight stock rail
Turnout plates No 11 and 12 to be furnished with heavy rails only, unless otherwise specified
Aline rails on turnout side when installing, to suit gages indicated
Note: Head 800 to be placed 17" from point when req'd. to provide for interlocking connections.

FROG NO	TIE SPACING R	S	T
5	19½	19	19
6	20½	20½	21


Angle at PT 4°30'
11'-0" Radius 2600'
Side Planing
DESIGN A
For Section at Point see Detail 5000 per Plan No 215.
This alinement to be furnished unless otherwise specified
Angle at PT 7°23'43"
11'-0" Radius 2492'
Side Planing
DESIGN B
For Section at Point see Detail 6000 per Plan No 215

WIDTH OF RAIL HEAD	SIDE PLANING DESIGN A	DESIGN B
2½"	5-7½	5-6⅞
2⅝"	5-10⅛	5-9½
2¾"	6-0¾	6-0⅛
2⅞"	6-3¼	6-2⅝
3"	6-5⅝	6-5⅛



Not less than 2½"
Omit spike hole "K" when distance "M" is less than 1½"
Omit spike holes "E" when distance "M" is less than ⅝"
All spike holes to be ½" ± ⅛" under edge of base.

PLATE NO.	DETAIL NO. 8"PL	7"PL	A	B	X
6	7102	6102	6⅜	5/16	5/16
8	7104	6104	10"	11/32	3/8
10	7106	6106	11¾	3/8	7/16
12	7108	6108	13⅜	13/32	½
5	7101	6101	6⅜	3/8	5/16
7	7103	6103	10⅜	13/32	3/8
9	7105	6105	12⅝	7/16	7/16
11	7107	6107	14⅝	7/16	½

7" AND 8" TURNOUT PLATES

Detail in table based on plates 8" wide.

GAGE OF TRACK

1- Gage of track as shown is recommended for general conditions and will provide proper clearance for the passage through the turnout of equipment having rigid wheel base not exceeding 12'0" in length with three pairs of flanged wheels or 14'6" in length for four pairs of flanged wheels.

2 For equipment having longer rigid wheel bases with more than two pairs of flanged wheels, consideration should be given to further increase in gage.

3- 4'-8½" gage may be used for equipment having no more than two pairs of flanged wheels on a rigid wheel base.

NOTES

1.—BILL OF MATERIAL, unless otherwise specified, will be furnished in accordance with the following specifications:
For heavy rails over 110 lb. per Spec. 121A.
For medium weight rails 80 lb. to 110 lb. inclusive, Spec 121B
Purchaser shall in all cases specify details of joint bars, especially as to size and location of holes required in rail ends, and as to size and location of spike notches, if any, for plate details
Purchaser shall specify hand and number of turnout and switch points and stock rails shall be alined to suit

2.—ALTERNATES:
(a) Alinement per design "B". Stock rails not furnished unless specified.
(b) Alinement for ¼" chamfered switch points per Plan No. 920. Stock rails not furnished unless specified.
(c) Any details of fittings that will apply per Plans No. 201, 202, 205, 206 and 215.
(d) Omit first 22" of stock rail side reinforcing, and place extra rivet between fifth and sixth holes
(e) Track Gage to suit equipment and Turnout Plates No. 5, 7, 9 and 11 revised accordingly.

3.—SPECIFICATIONS—See Appendix "A".

Plan No. 121 Spec. 121A — BILL OF MATERIAL — Detail No.
11'-0" Curved Split Switch
For Heavy Rails Only

		Detail No.
2	Double Reinforced Switch Points Complete, Design A, with details: For Planing	5000
	For ¾" Side Jaw Clips	3012
	For Stops	2024
1	R.H and 1 L.H. Machined Stock Rails 39'-0" Long.	
2	Insulated Switch Rods	
	1 No 1—2½" x 1¼"	6010
	1 No. 2—2½" x 1¼"	6011
	Insulation applied to Rods No. 1 and 2	3001 or 3002
10	Adjustable Rail Braces per Plan No. 240.	
10	Solid Base Slide Plates 8" wide for use with Adjustable Rail Braces	
	2 No. 0, 4 No. 1A and 4 No. 1	7020
4	Solid Base Slide Plates 8" Wide—Plain—No 2	7021
4	Heel Plates 8" Wide	
	1 Pr. No. 3 R.H and L.H	7040
	1 Pr. No. 4 R.H and L.H	7049
8	Turnout Plates 6" Wide	
	1—No. 5	7101
	1—No. 6	7102
	1—No. 7	7103
	1—No. 8	7104
	1—No. 9	7105
	1—No. 10	7106
	1—No. 11	7107
	1—No. 12	7108
2	Heel Blocks Complete with Bolts, Joint Bars and Thimbles	2025

Additional equipment to be furnished when specified.

Gage Plates. Location to be specified; number of slide plates reduced accordingly		7026

Plan No. 121 Spec. 121B — BILL OF MATERIAL — Detail No.
11'-0" Curved Split Switch
For Medium Weight Rails Only

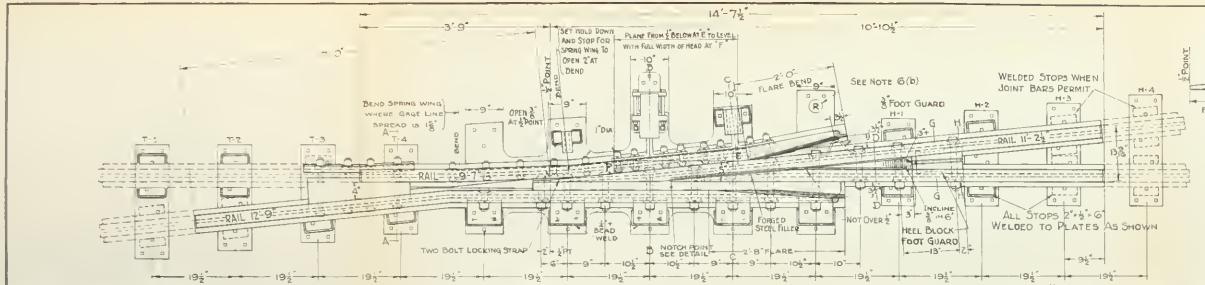
		Detail No.
2	Double Reinforced Switch Points Complete, Design A, with details: For Planing	5000
	For ¾" Side Jaw Clips	2012
	For Stops	1024
1	R.H and 1 L.H Machined Stock Rails 39'-0" Long.	
2	Insulated Switch Rods	
	1—No 1—2½" x 1"	2010
	1—No. 2—2½" x 1"	2011
	Insulation applied to Rods No. 1 and 2	3001 or 3002
10	Adjustable Rail Braces per Plan No. 240	
10	Solid Base Slide Plates 7" wide for use with Adjustable Rail Braces	
	2 No. 0, 4 No. 1A and 4 No. 1	6020
4	Solid Base Slide Plates 7" wide—Plain—No. 2	6021
4	Heel Plates 7" Wide	
	1—Pr. No. 3 R.H and L.H	6040
	1—Pr. No. 4 R.H and L.H	6049
6	Turnout Plates 7" Wide	
	1—No. 5	6101
	1—No. 6	6102
	1—No. 7	6103
	1—No. 8	6104
	1—No. 9	6105
	1—No. 10	6106
2	Heel Blocks Complete with Bolts, Joint Bars and Thimbles	2025

Additional equipment to be furnished when specified

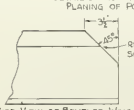
Gage Plates. Location to be specified number of slide plates reduced accordingly		6026

A. R. E. A.
11'-0" CURVED SPLIT SWITCH WITH UNIFORM RISERS

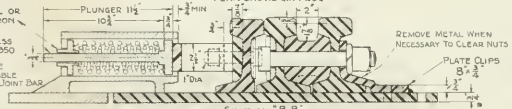
PLAN NO. 121

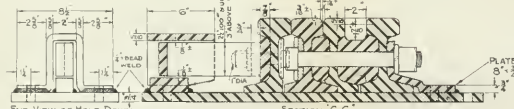


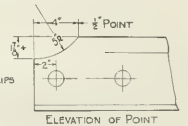
FULL WIDTH OF RAIL HEAD
FOR WIDTH OF RAIL HEAD 2⅜" OR MORE
LONG POINT
SHORT POINT
2⅛" FOR WIDTH OF RAIL HEAD LESS THAN 2⅜"
SLOPE ⅜ IN 10"
POINT
DETAIL OF NOTCHING AND PLANING OF POINTS



FORGED STEEL OR MALLEABLE IRON
SPECIAL THIMBLE BRINNELL HARDNESS OF NOT LESS THAN 350
MACHINE SQUARE BEARING FOR THIMBLE IN TOE BLOCK AND JOINT BAR
SECTION 'A-A'


PLUNGER 11½
REMOVE METAL WHEN NECESSARY TO CLEAR NUTS
PLATE CLIPS
SECTION 'B-B'
Double Spring 8¾" Long { Outside Coil ¾" I.D. ⅝" Round Steel 10 R.H. Coils
Inner Coil 1⅛" I.D. ⅝" " 14 L.H. "





NOTES

1—DETAIL OF JOINT BARS—Purchaser shall in all cases supply details of joint bars, especially as to size and location of holes required in rail ends and as to size and location of spike notches, if any, for tie plate punching

2—FILLERS—Main Filler shall be of rolled steel in one continuous length, preferably single groove section, and shall maintain the required flangeway throughout. Heel block foot guard to be of cast iron

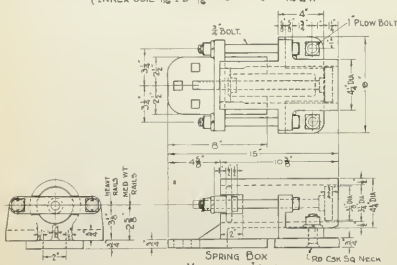
3—HEEL RISER BLOCK—Heel Riser Block shall be of steel rail, head up, with flange upset to fit properly over and rest upon the bases of the adjoining rails, or of other approved design that will insure a proper bearing on bases of the point rails and will provide rolled or forged steel wearing surface equal in hardness to rail steel

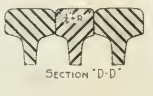
4—PLATES—Loose Tie Plates shall be 8" wide and ½" thick. Plates T1, T2, T3, T4, H3 and H4 shall have holes adjacent to rails punched to match spike notches of joint bars if any.

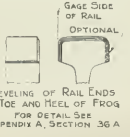
5—SPIKE HOLES—Adjacent to rail to be ¾" x ¾"—¾" under edge of base. Others to be ¾" square

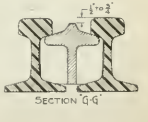
6—ALTERNATES to be furnished when specified
(a) Additional plates for succeeding ties at toe and heel where standard tie plates cannot be used without cutting
(b) Spring Wing Retarder of approved design on tie plate 'R'

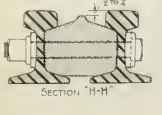
7—SPECIFICATIONS—See Appendix "A". Bolt sizes and details shall be per Section 1402, Appendix "A"

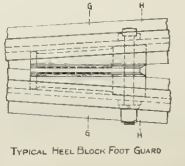












A. R. E. A.

NO. 10 SPRING RAIL FROG FOR HEAVY AND MEDIUM WEIGHT RAILS. SHORT SPRING RAIL TYPE.

PLAN NO. 405

As the widening of the gage is necessary at the point of the switch, the gage through the straight run must necessarily be increased correspondingly at that point.

In order to avoid complication of details at heel blocks it is recommended that the widened gage be carried to the heel of the switch as shown on the plan.

If the equipment that is used through the turnout run will have no more than two pairs of flanged wheels on a rigid wheel base, standard gage may be used throughout the switch.

The following plan has been prepared to show all of the necessary details for the construction and application of 11-ft. Curved Switches:

Plan No. 121—11-Ft. Curved Split Switch with Uniform Risers.

This plan completes the series of detail plans for curved switches.

Spring Rail Frogs

Further study has been given to the subject of Spring Rail Frogs, resulting in the preparation of a detail plan for a short spring rail type with a heavy base plate support and suitable for use in heavy main line service where traffic is infrequent through the turnout run. At locations where it is necessary to make more frequent moves through the turnout run, but desirable to provide good surface for high speed traffic through the main track run, provision has been made for the application of a retarding device to check the return of the spring rail and greatly reduce the destructive effect on the frog of the blow delivered by the return of the spring rail after the passage of each wheel. These features are shown on—

Plan No. 405—No. 10 Spring Rail Frog for Heavy and Medium Weight Rails—Short Spring Rail Type.

The Standardization committee of the Manganese Track Society has co-operated in the preparation of these plans and specifications, and rendered valuable assistance.

Conclusions

The committee recommends that—

Plan No. 121—11-Ft. Curved Split Switch with Uniform Risers,

Plan No. 405—No. 10 Spring Rail Frog for Heavy and Medium Weight Rails—Short Spring Rail Type,

be adopted as recommended practice and published in the Manual.

The committee recommends that the work be continued.

Appendix E

(5) CORROSION OF RAILS AND FASTENINGS IN TUNNELS

A. E. Perlman, Chairman, Subcommittee; W. H. Bettis, R. W. E. Bowler, O. U. Cook, L. W. Deslauriers, T. T. Irving, E. E. Martin, S. H. Poore, G. L. G. Smith, Dr. Hermann von Schrenk.

Sixteen railroads in the United States and Canada, experiencing difficulties due to corrosion of rails and fastenings in tunnels, report rail life below eight years, and two of these obtain only two years' life.

No thoroughly satisfactory answer to the problem has been found to date. Tie plates, spikes, and fastenings are protected in varying degree by various coatings. The rail can be so protected over all of its surface except the running surface. Without this vital protection, head wear is found to be greatly accelerated.

There are two general causes of corrosion—electrical and chemical—from stray current electrolysis and acids, or other corrosive chemicals in solution.

The first of these may be passed over with the recommendations that individual railroads make a survey in their tunnels to determine the possible presence of positive potentials in the rails, and eliminate them or drain them away with proper groundings.

Of the second general cause, it can be stated that carbon dioxide and sulphur dioxide are the chief causes of corrosion in tunnels. These gases come from the burning of coal through the tunnels, and, when dissolved in condensate from the stack, form acid solutions which are very corrosive. Of the two gases, sulphur dioxide is by far the more corrosive. If it can be eliminated or neutralized, it is felt that corrosion can be very materially reduced.

The subcommittee is gathering information from the railroads involved, concerning the analysis of the coal used, for sulphur content, the analysis of the ash from the coal for amount of soluble alkaline material, and the amount of coal burning per year through the tunnel. This data, in connection with figures showing the average rail life, should give an indication of the relative importance of the two corroding agents.

It is recommended that the following suggestion be offered to the member railroads: In some cases it is possible to build up a sufficient bed of coal in the firebox before entering a tunnel to carry the train through without adding more coal while in the tunnel, or keep the addition to a minimum.

Extensive studies have been made by your subcommittee in a tunnel 6.2 miles in length. Weighed test pieces were placed in the tunnel and examined after several weeks. The pieces were coated with various commercial rust proofing compounds and various metals. Penetration was merely a matter of time, even for heavy coatings. Laboratory and tunnel tests of cathodic protection, such as is used successfully on underground structure, were tried without effect, since there is no conductor surrounding the rail.

Laboratory analysis of the ash of two kinds of coal used showed that one of them contained soluble alkaline material, whereas the other did not. The alkaline ash should aid in neutralizing acid fumes.

Various alloy steels were tried unsuccessfully, but others are being investigated. The use of lime blown through the firebox, as the engine goes through the tunnel, is now being investigated and results will be known soon.

This is submitted as a progress report.

Appendix F

(7) PRACTICABILITY OF USING REFLEX UNITS FOR SWITCH LAMPS AND TARGETS

G. L. Sitton, Chairman, Subcommittee; L. L. Adams, F. J. Bishop, E. E. Martin, S. N. Mills, I. H. Schram, J. F. Shaffer, M. J. T. Zeeman.

The latest report containing information on this subject was made in 1933, at which time three railroads were reported as having appreciable numbers of units in service and appeared definitely committed to their use.

This year all roads represented on the track committee, and other roads known to have experimented with reflex units, have been contacted by means of a questionnaire. The following gives a general idea of the information received:

11 roads report no experience and little interest.

13 roads report a total of 4588 units in service.

The general preference is for—

First choice, four reflex lenses mounted in a housing to replace switch lamp.

Second choice, reflex lenses used to replace lenses in existing switch lamps, there being a decided trend away from button-type units.

Nine roads have passed the experimental stage, and ten expect to increase the number in service.

Reports received indicate that reflex units are generally practicable at the following locations:

(a) Main-track switches in automatic signal territory more than 500 ft. from the signal.

(b) Main-track switches outside automatic signal territory.

(c) Switches leading from passing or other side tracks.

In general, reflex units are considered practicable wherever oil or electric switch lamps are practicable, except under conditions where light cannot be reflected, as is the case where cars are handled between the headight and the switch and where back-up movements are made without a headlight on rear.

The reports received indicate generally that reflex units are distinguishable as to color as far as oil or electric switch lamps, and through angles as great as lamps.

Reports received give the following annual costs:

	Average	*Minimum*	*Maximum*
Oil-lighted switch lamps	$20.79	$11.08	$30.00
Electric-lighted switch lamps	10.50	3.00	15.00
Reflex units	2.37	.75	6.00

Attention is directed to the fact that, on the basis of the above costs, the annual saving incident to the operation of the 4,588 reflex units referred to above, as compared with the cost of operation of a similar number of oil lamps, is in excess of $84,000.

With the exception of one road reporting, all roads retain the switch target for day indication.

Only one road favors the outlining of switch targets by means of reflector buttons.

The laws of some states are worded so as to prohibit the use of reflector units—information not complete.

A few cases have been reported where enginemen and conductors have complained that they were unable to tell when a switch at the rear of the train was thrown, but generally these complaints have not been considered sufficient to justify discontinuance of reflex units.

Reports indicate little, if any, decrease in efficiency as compared with oil or electric switch lamps, due to adjacent illumination, or to fog or smoke.

One road reports that greater visibility due to reflected sunlight makes reflex units better targets for hunters and boys. On the other hand, the fact that reflex units are less visible at night unless light is reflected from them, should make them less liable to be broken at night.

While most of the roads reporting advise that they have had no trouble on account of snow and ice accumulations, it is felt that this information should not be considered conclusive for the reason that approximately half of the reporting roads do not lie in northern territory and that in some cases northern roads have been prevented this form of trouble by burning oil in cold weather. This, of course, cannot be done where oil lamps have been replaced by specially designed units.

This report is offered as information.

Appendix G

(8) WELDING OF MANGANESE CASTINGS IN SPECIAL TRACKWORK

F. J. Bishop, Chairman, Subcommittee; Lem Adams, A. L. Bartlett, W. H. Bettis, E. W. Caruthers, O. H. Frick, H. H. Harman, F. W. Hillman, C. T. Jackson, G. M. Magee, F. H. Masters, I. H. Schram, G. J. Slibeck, H. N. West.

A report on this subject was presented to the Association last year in Volume 39 of the Proceedings pp. 416–419, inclusive.

In its further study of this subject the committee has found a diversity of opinion on many important elements and that some research work was advisable. After considerable study on the subject, a program of research has been prepared for developing the desired information. The principal topics for study are as listed below:

Scope of Research Program

1. Effect of different currents and amperages
2. Effect of different compositions of rods
3. Effect of use of cutting torch
4. Effect of welding with filler bars
5. Effect of welding on preground surface
6. Welding with ac. versus dc.
7. Effect of welding on nickel manganese steel and initial properties of nickel-manganese compared to high manganese
8. Effect of coating on welding roads
9. Effect of temperature on welding
10. Effect of peening during welding
11. Effect of welding in wind or rain
12. Effect of retreating manganese after welding
13. Testing welds by magnetic induction

Several manufacturers have offered to furnish part of the necessary castings, together with patterns for them, and it is the hope of the committee that sufficient castings will be obtained in the near future to proceed with the research program. Several railroads have also offered to install the castings in some of their tracks as well as make the necessary welds.

The report is offered as information with the recommendation that the subject be continued.

Appendix H

(9) BOLT TENSION NECESSARY FOR PROPER SUPPORTING OF RAIL JOINTS

C. W. Breed, Chairman, Subcommittee; C. W. Baldridge, A. L. Bartlett, E. D. Cowlin, L. W. Deslauriers, H. F. Fifield, F. S. Hales, C. T. Jackson, J. de N. Macomb, G. M. Magee, F. H. Masters, W. A. Murray, S. H. Poore, G. M. Strachan, J. N. Todd.

Preliminary to the study of bolt tension, the committee decided upon a program of tests:

1. To determine tension in bolts at time of rail laying resulting from use of power and hand wrenches.

2. To record at regular intervals loss or stability of tension.

3. To determine effect on tension of length or kinds of joint bars, of number of bolts in joints, of kind of spring washers or absence of spring washers, of kind of threads on bolt and in nut.

4. To develop a practical method of setting up bolts to predetermined tension.

5. To determine relation between bolt tension and slip of rail in joint, including laboratory tests.

The measurement of bolt tension was made by means of a caliper extensometer of the kind shown in Fig. 1.

Fig. 1.—Bolt Tension Extensometer.

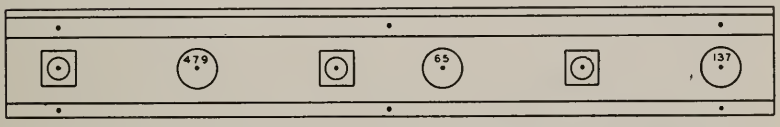


Fig. 2.—Method of Preparing Joint Bar and Bolts for Test. (Dots indicate location of countersunk holes).

The bolts for the tests were prepared by having seats for the conical points of the caliper drilled into each end, and were number-stamped on the head for identification. The no-load length was carefully measured and recorded for each bolt before installing in track, with two or more measurements of each bolt to insure accuracy, and standard reference bolts were recorded and set aside for use throughout the test. During the time measurements were made in track, reference bolt was maintained at the same temperature as the bolts in the joint so that corrections for temperature changes were unnecessary. A check was made on the reference bolt at each joint, and care was exercised to prevent the dial or movable parts of the instrument receiving any contact that might affect its adjustment.

Six punch-marks were made on the outer face of all joint bars in the test section, as shown in Fig. 2, for the purpose of measuring the effect of tension on the wear of joint bars and rail fishing surfaces.

The out-to-out distance between bars was carefully measured by means of a micrometer caliper (Fig. 3). Periodical measurements will subsequently be made. Monuments were placed at each end of test section to determine the extent of rail movement

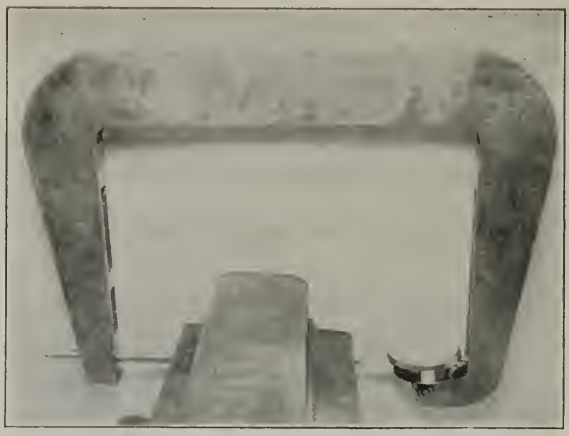


FIG. 3.—Joint Caliper.

and its relation to bolt tension. Joint gaps were measured and recorded at the time of rail laying and will be measured and recorded at regular intervals to determine the variation under service and seasonable temperature changes and known bolt tension.

Tests

The first test lot of 395 bolts was installed on the Chicago, Milwaukee, St. Paul & Pacific Railroad near Winona, Minn., in the westbound main line between Chicago and St. Paul on July 22, 1938. This track, which is on level grade and tangent, was laid with 112-lb. rail, 6-hole toeless joint bars with 1-in. bolts but no spring washers. Woolery power wrenches without a kick-off were employed to tighten the bolts. The test bolts were applied in connection with the rail laying by the steel gang. The condition of the ties and ballast was good. Rail laying had just been completed and ballasting with gravel was in progress.

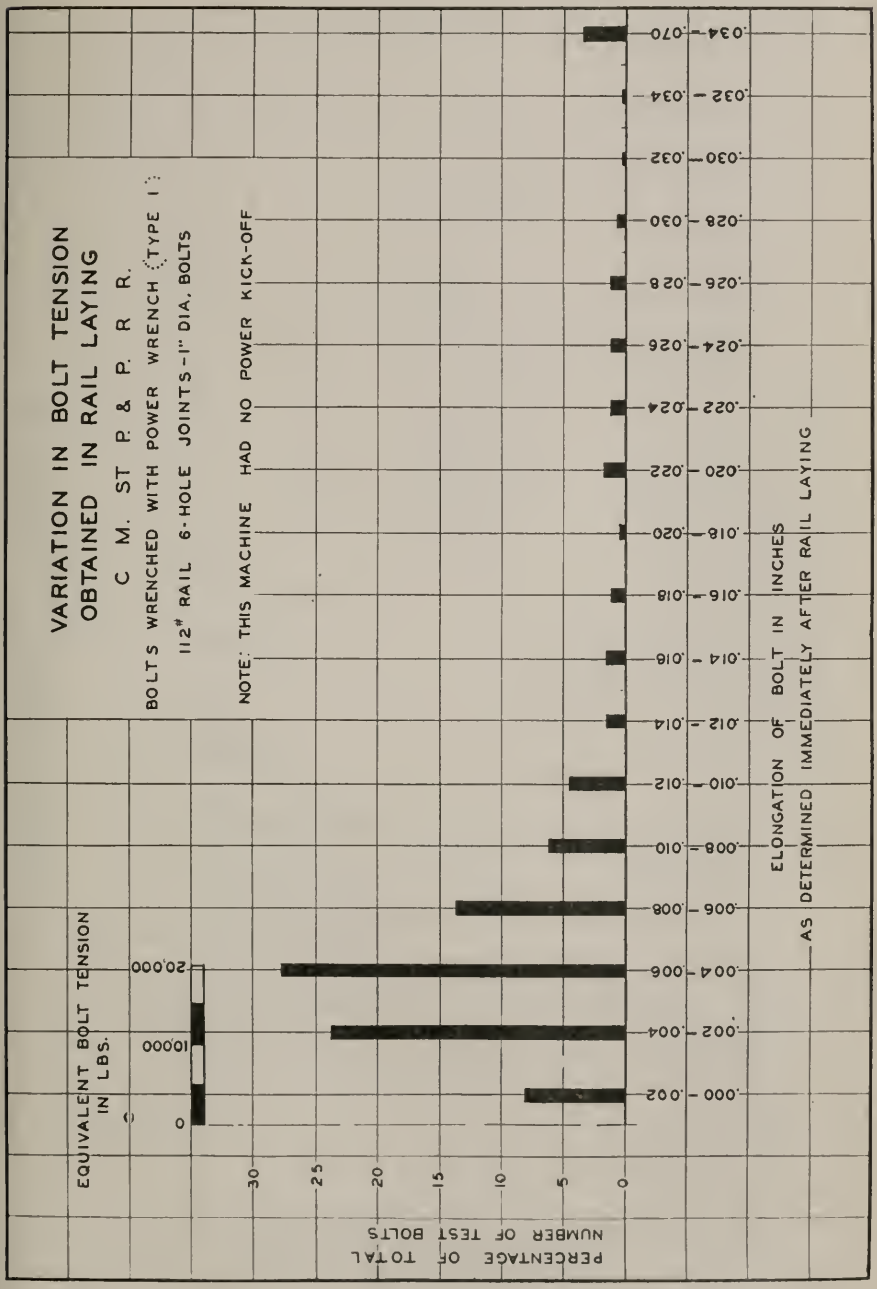
Here, as in all subsequent tests, bolt tensions were found to cover a wide range, and a considerable number were beyond the elastic limit. This test should develop important data with reference to bolt tension without the use of spring washers.

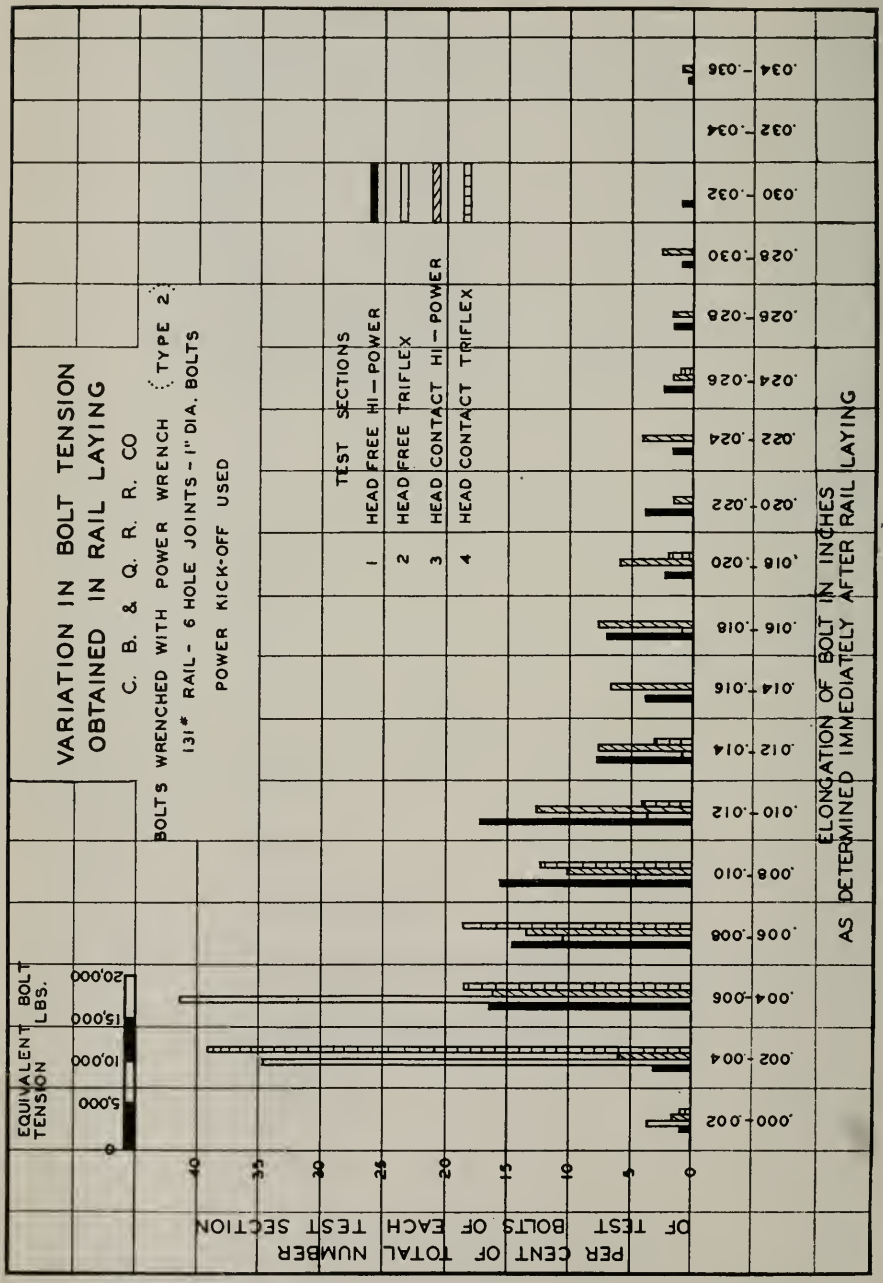
The second test was installed August 9, 1938, on the Chicago, Burlington & Quincy Railroad 16 miles west of Chicago in the eastbound main track. There were 480 bolts in this test. The track, which is on level grade and tangent, was laid with 131-lb. rail, 6-hole toeless joint bars, 1-in. bolts and spring washers. Nordberg power wrenches with a kick-off were used. The test bolts were applied in connection with rail laying by the steel gang. The condition of the ties and chat ballast was good.

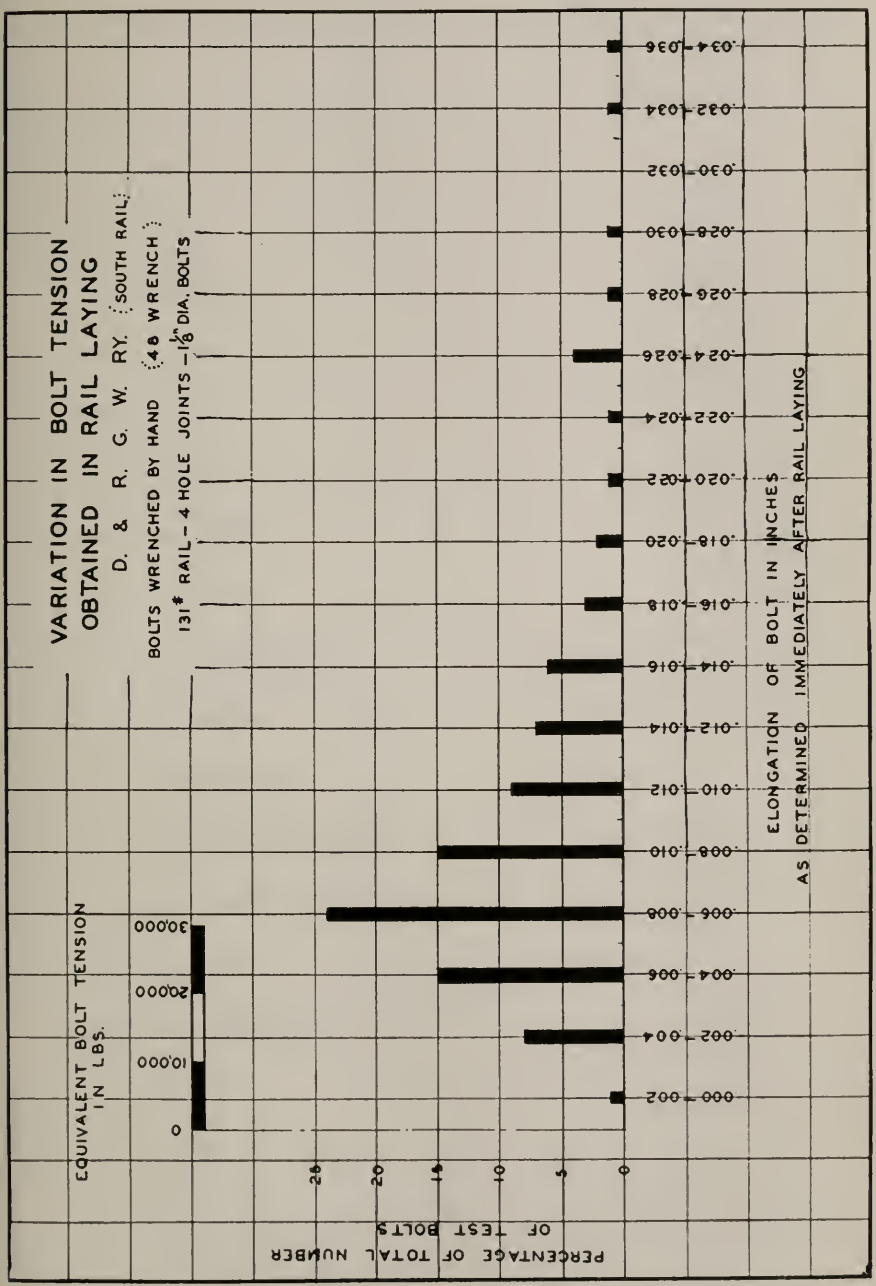
In this test two types of joint bars were used, head-free and head-contact, and with each, half the bolts were equipped with Double Hi-Power spring washers and half with Triflex springs.

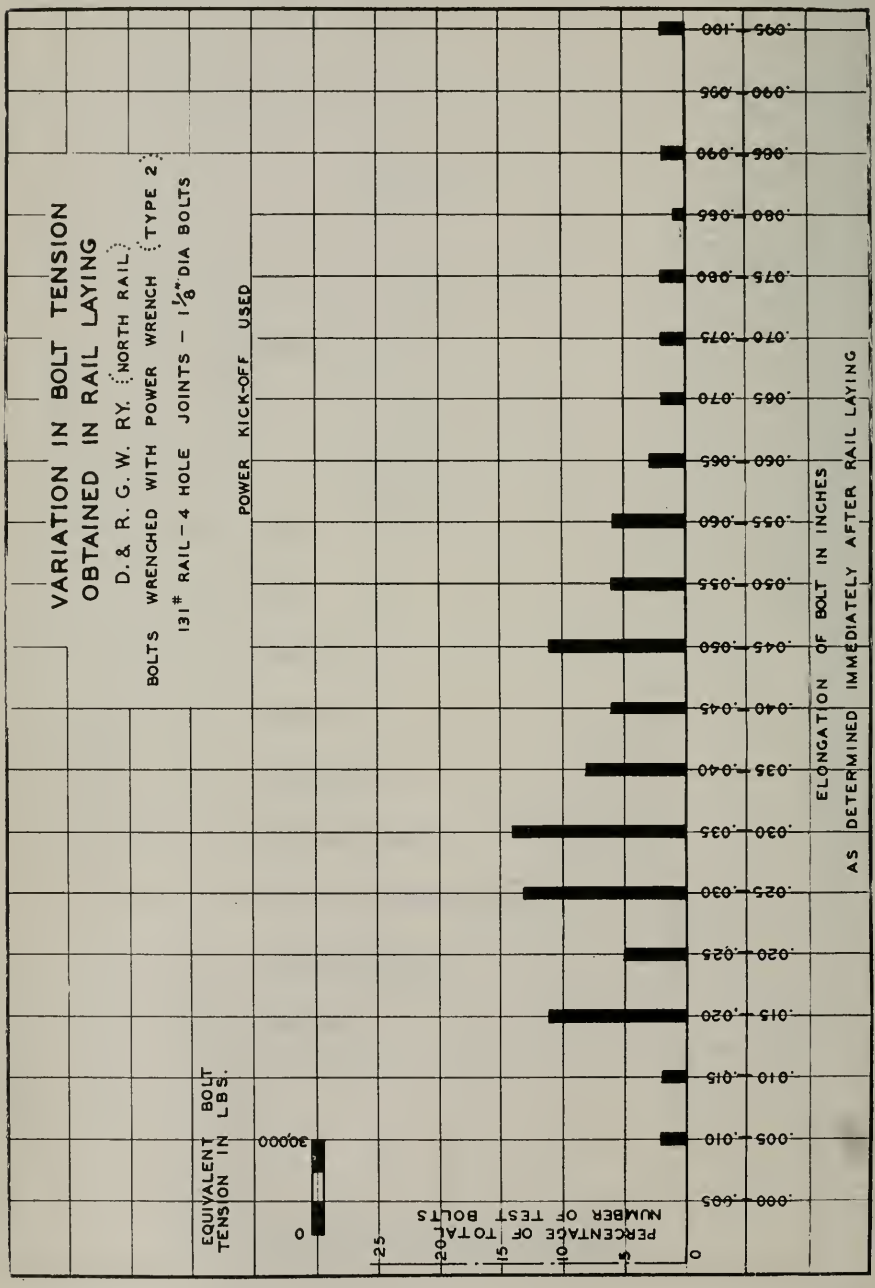
The power wrenches employed were adjusted to kick off when a 15,000-lb. tension was reached.

On October 5, 1938, the tension was measured in a portion of the bolts to record the loss of tension since the initial installation, after which all nuts of test bolts were loosened and the unloaded length of bolts recorded. Then all bolts on the south rail were given approximately 15,000 lb. of tension, and on the north rail, 25,000 to 30,000 lb.


VARIATION IN BOLT TENSION
OBTAINED IN RAIL LAYING
C M. ST P. & P. R R.
BOLTS WRENCHED WITH POWER WRENCH (TYPE I)
112# RAIL 6-HOLE JOINTS-1" DIA. BOLTS
NOTE: THIS MACHINE HAD NO POWER KICK-OFF
EQUIVALENT BOLT TENSION IN LBS.
20,000
10000
0
PERCENTAGE OF TOTAL NUMBER OF TEST BOLTS
30
25
20
15
10
5
0
.000 - .002
.002 - .004
.004 - .006
.006 - .008
.008 - .010
.010 - .012
.012 - .014
.014 - .016
.016 - .018
.018 - .020
.020 - .022
.022 - .024
.024 - .026
.026 - .028
.028 - .030
.030 - .032
.032 - .034
.034 - .070
ELONGATION OF BOLT IN INCHES
AS DETERMINED IMMEDIATELY AFTER RAIL LAYING


VARIATION IN BOLT TENSION OBTAINED IN RAIL LAYING
C. B. & Q. R. R. CO
BOLTS WRENCHED WITH POWER WRENCH (TYPE 2)
131# RAIL - 6 HOLE JOINTS - 1" DIA. BOLTS
POWER KICK-OFF USED
EQUIVALENT BOLT TENSION LBS.
0
5,000
10,000
15,000
20,000
TEST SECTIONS
1 HEAD FREE HI-POWER
2 HEAD FREE TRIFLEX
3 HEAD CONTACT HI-POWER
4 HEAD CONTACT TRIFLEX
PER CENT OF TOTAL NUMBER OF TEST BOLTS OF EACH TEST SECTION
40
35
30
25
20
15
10
5
0
.000-.002
.002-.004
.004-.006
.006-.008
.008-.010
.010-.012
.012-.014
.014-.016
.016-.018
.018-.020
.020-.022
.022-.024
.024-.026
.026-.028
.028-.030
.030-.032
.032-.034
.034-.036
ELONGATION OF BOLT IN INCHES AS DETERMINED IMMEDIATELY AFTER RAIL LAYING


VARIATION IN BOLT TENSION
OBTAINED IN RAIL LAYING
D. & R. G. W. RY. SOUTH RAIL
BOLTS WRENCHED BY HAND 48 WRENCH
131# RAIL – 4 HOLE JOINTS – 1⅛" DIA. BOLTS
EQUIVALENT BOLT TENSION IN LBS.
0
10,000
20,000
30,000
PERCENTAGE OF TOTAL NUMBER OF TEST BOLTS
25
20
15
10
5
0
.000 – .002
.002 – .004
.004 – .006
.006 – .008
.008 – .010
.010 – .012
.012 – .014
.014 – .016
.016 – .018
.018 – .020
.020 – .022
.022 – .024
.024 – .026
.026 – .028
.028 – .030
.030 – .032
.032 – .034
.034 – .036
ELONGATION OF BOLT IN INCHES
AS DETERMINED IMMEDIATELY AFTER RAIL LAYING


VARIATION IN BOLT TENSION
OBTAINED IN RAIL LAYING
D. & R. G. W. RY. NORTH RAIL TYPE 2
BOLTS WRENCHED WITH POWER WRENCH
131# RAIL – 4 HOLE JOINTS – 1⅛" DIA BOLTS
POWER KICK-OFF USED
EQUIVALENT BOLT TENSION IN LBS.
30000
0
PERCENTAGE OF TOTAL NUMBER OF TEST BOLTS
25
20
15
10
5
0
.095 – .100
.090 – .095
.085 – .090
.080 – .085
.075 – .080
.070 – .075
.065 – .070
.060 – .065
.055 – .060
.050 – .055
.045 – .050
.040 – .045
.035 – .040
.030 – .035
.025 – .030
.020 – .025
.015 – .020
.010 – .015
.005 – .010
.000 – .005
ELONGATION OF BOLT IN INCHES
AS DETERMINED IMMEDIATELY AFTER RAIL LAYING

On November 1, the tension in these bolts was again measured, which practice will be continued. Information on these measurements will be presented in next year's report.

The third test was installed September 7, 1938, on the Denver & Rio Grande Western Railroad in the main line near Glenwood Springs, Colo. The track, which is on level grade and on both tangent and curve, was laid with 131-lb. rail, 4-hole toeless joint bars, 1⅛-in. bolts with National grooved spring washers.

Hand wrenching with 48-in. wrenches was employed to tighten the bolts, on the south rail and a Nordberg power wrench with a kick-off on the north rail. The condition of the ties and slag ballast was good. Here the test bolts were tightened by a special gang working behind the steel gang. On November 9, 1938, the tension of the bolts in the test was remeasured but too late to be included in this year's report.

General

The work of this subcommittee has not progressed to such an extent that conclusions or recommendations can be made. We hope to install other tests on eastern railroads during the spring of 1939.

Considerable effort has been made to develop means for setting up a predetermined tension in bolts with encouraging success.

The report is offered as information with the recommendation that the subject be continued.

Appendix I

(10) LUBRICATION OF RAIL ON CURVES

F. S. Hales, Chairman, Subcommittee; L. L. Adams, W. H. Bettis, L. H. Bond, R. W. E. Bowler, A. F. Huber, T. T. Irving, F. J. Jerome, E. E. Martin, A. E. Perlman, S. H. Poore, G. L. G. Smith, C. R. Strattman.

A tentative report on this subject was made in 1938 and printed in AREA Proceedings Vol. 39, page 419, in which four methods of lubrication were listed and in which one method of determining the economy of rail lubricators was described. The 1938 report also listed certain items for further study. Additional work has been done on this subject.

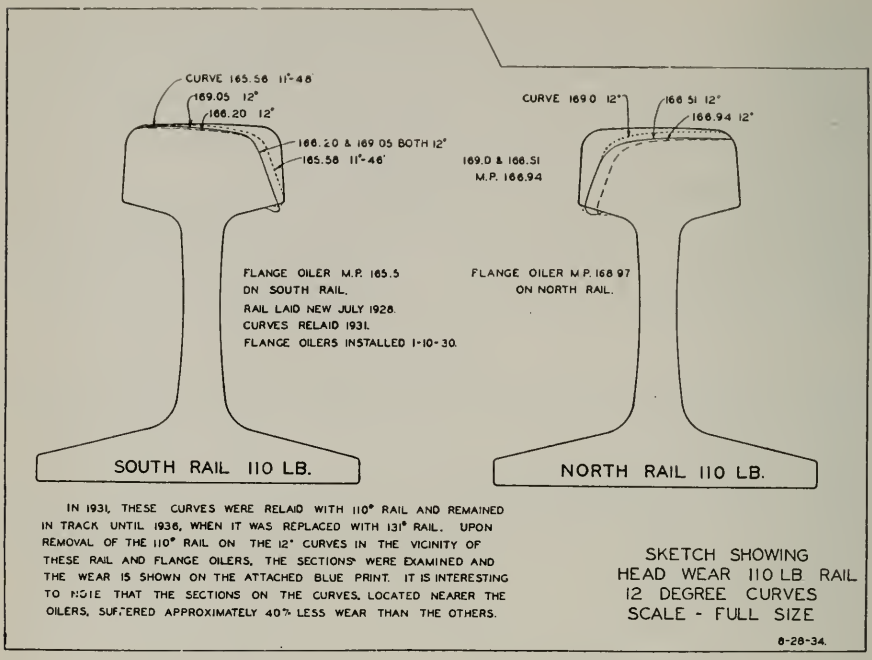
The committee has not so far been able to obtain any conclusive information relative to the following:

Relation between degree of curve and increased life of rail lubricated.
Decreased amount of train resistance, with respect to tonnage and curvature.
Decreased amount of wear on engine tires.

The following additional information has been compiled on the methods of lubrication and the results of lubrication, including a few charts showing rail wear before and after lubrication.

Mechanical Lubricators Installed in Track

From all information which has been received it is evident that the annual cost of a rail lubricator is from $100 to $150, averaging approximately $140. This average cost is divided approximately $75 for interest and depreciation, $30 for grease and $35 for labor and repairs. This cost will vary with traffic, as the amount of lubricant used varies with number of wheels. The committee will go into this further. See example at end of this appendix.


CURVE 165.56 11°-48'
169.05 12°
166.20 12°
166.20 & 169.05 BOTH 12°
165.58 11°-46'
CURVE 169.0 12°
166.51 12°
166.94 12°
169.0 & 166.51
M.P. 166.94
FLANGE OILER M.P. 165.5
ON SOUTH RAIL.
RAIL LAID NEW JULY 1928.
CURVES RELAID 1931.
FLANGE OILERS INSTALLED 1-10-30.
FLANGE OILER M.P. 168.97
ON NORTH RAIL.
SOUTH RAIL 110 LB.
NORTH RAIL 110 LB.
IN 1931, THESE CURVES WERE RELAID WITH 110# RAIL AND REMAINED IN TRACK UNTIL 1936, WHEN IT WAS REPLACED WITH 131# RAIL. UPON REMOVAL OF THE 110# RAIL ON THE 12° CURVES IN THE VICINITY OF THESE RAIL AND FLANGE OILERS, THE SECTIONS WERE EXAMINED AND THE WEAR IS SHOWN ON THE ATTACHED BLUE PRINT. IT IS INTERESTING TO NOTE THAT THE SECTIONS ON THE CURVES, LOCATED NEARER THE OILERS, SUFFERED APPROXIMATELY 40% LESS WEAR THAN THE OTHERS.
SKETCH SHOWING
HEAD WEAR 110 LB RAIL
12 DEGREE CURVES
SCALE - FULL SIZE
8-28-34.

The effective distance which lubrication will carry is a subject upon which the committee has received many estimates covering a wide range, although approximately 5,000 ft. is an estimate which is quite generally used. However, there are many locations where lubricant has been carried 4 to 10 miles. The committee has attempted to find some relationship between the length of rail lubricated and the degree of curvature, but has not been very successful in getting this information from the railroads. One manufacturer advises that from studies made by his company, the lubricant is effective for 400 deg. of central angle, which would be 10,000 feet of 4 deg. curve. An actual investigation on one railroad at one location verifies this, but the curves were close together and were between 2 deg. and 4 deg.

The kind of lubricant most satisfactory in mechanical track lubricators is a grease or oil of heavy consistency. The consistency of greases and oils varies considerably, and the specific lubricant to be used can best be determined by actual experience, based on specific locations and climatic conditions.

Mechanical Flange Lubricators on Locomotives

The small locomotive flange lubricators, now in use, apply oil to locomotive drivers only. For this reason and also because of the type of oil used, it is very difficult for such a lubricator to transmit sufficient lubricant to protect any quantity of rail or wheels. At most, only the first few wheels directly back of the locomotive are benefited. The use of this type of lubrication seems to be decreasing and the committee has obtained very little information concerning it.

Mechanical Lubricators on Locomotives Applying Lubricant Direct to Rail

For the past four years, one railroad has been applying lubricant direct to the rail by means of a mechanical lubricator on the locomotive, but it is said that this has not been in service long enough for the determination of actual savings. A statement has been prepared, however, that shows the estimated savings, and this is presented in the table.

SAVING EFFECTED IN RAIL WEAR BY ENGINE LUBRICATION
HIGH SIDE OF CURVES—FOUR-DEGREE AND OVER

Division	*Number of curves 4 deg. and over lubricated by engine oilers*	*Total length, high side only*	*Life new rail before oiled*	*Life new rail after oiled*	*Saving per year new rail, tons*	*Net value per ton*	*Total net annual saving*
A	459	518,100	2.66	4.	600	$20.95	$12,570.00
					385 relay	11.30	4,350.50
Labor saved						2.00	1,970.00
B	726	399,059	4.48	6.	341	20.95	7,143.95
Labor saved						2.00	682.00
C	115	120,384	6.	8.	76	20.95	1,592.20
Labor saved						2.00	152.00
D	714	423,764	8.21	9.24	100	20.95	2,095.00
					32 relay	11.30	361.60
Labor saved						2.00	264.00
E	87	91,000	5.4	8.4	91	20.95	1,906.45
Labor saved						2.00	182.00
F	303	258,928	3.5	5.	335	20.95	7,018.25
Labor saved						2.00	670.00
Total	2,404	1,811,235 (343 miles)	4.84	6.30	1,960		$40,957.95

SUMMARY OF SAVING

1,543 tons new rail @ $20.95	$32,325.85
417 tons relay rail @ $11.30	4,712.10
Labor saving on 1,960 tons rail @ $2.00	3,920.00
	$40,957.95

Manual Lubrication of Rail

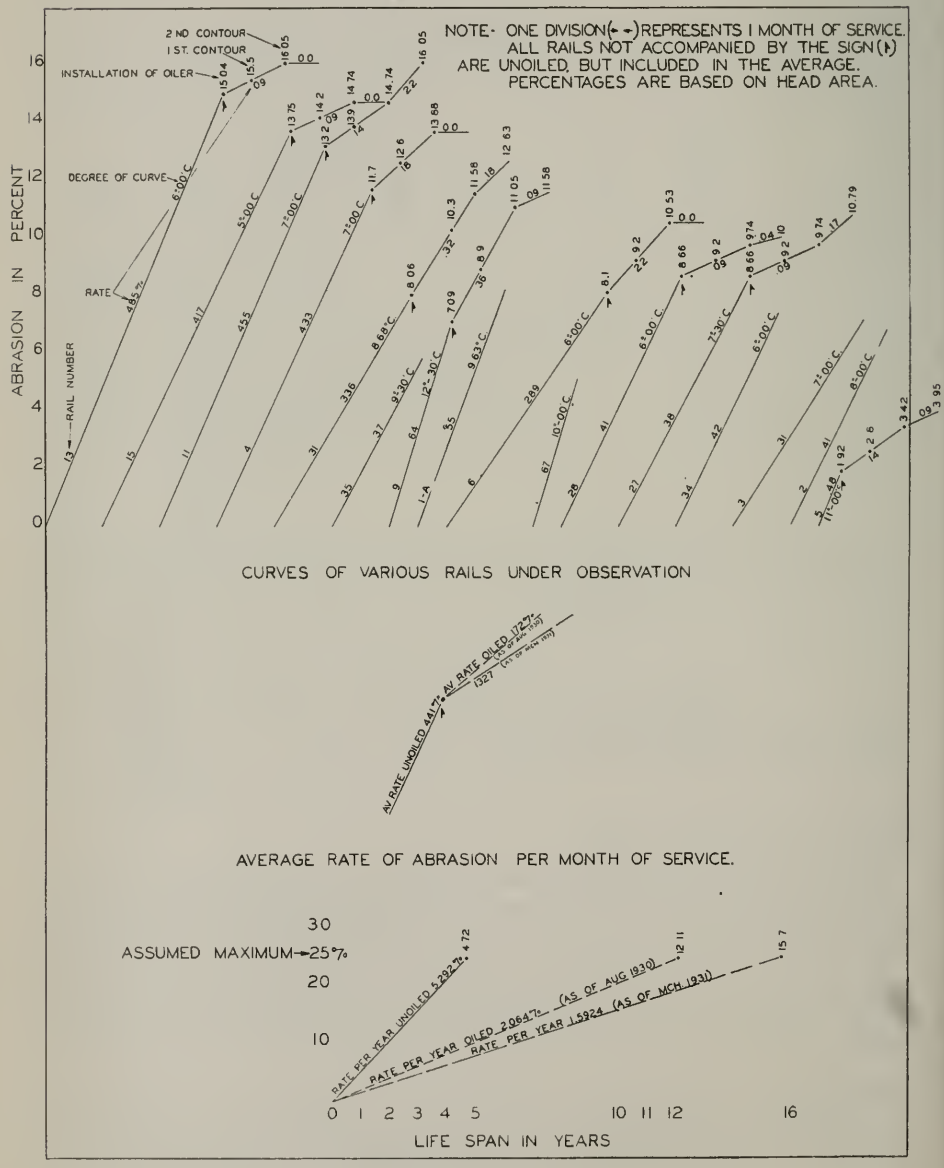
In most instances, manual lubrication is expensive, but may be economical on isolated short sharp curves in heavy traffic territory where the mechanical method would not be economically justifiable. The method commonly used is the application of the lubricant by a pail and brush or small wooden paddle. There has also been developed and patented a portable hand operative rail lubricator which is working satisfactorily on one railroad. Without doubt, there are locations where this is the most economical method of lubricating rail.

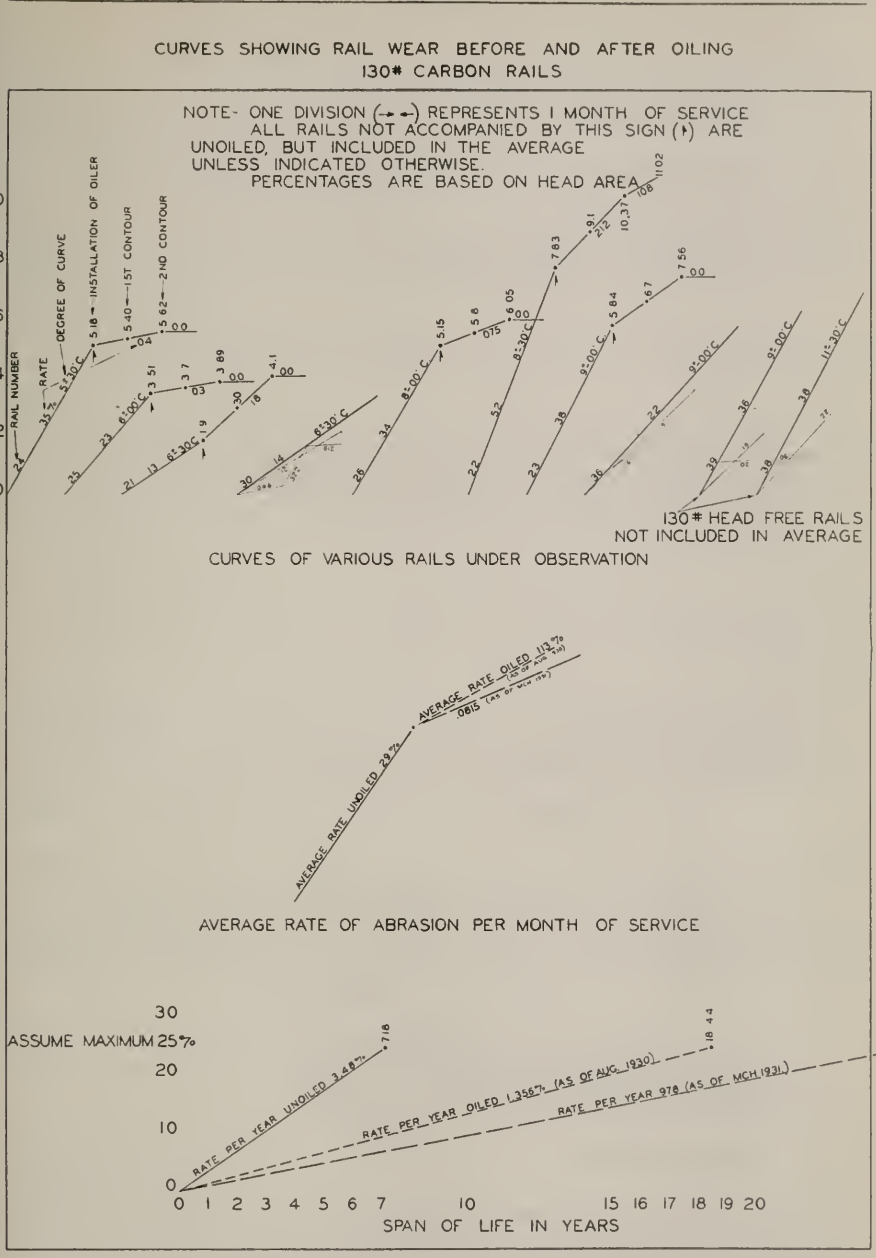
Conclusions

The life of rail on curves can be extended by the lubrication of the rails. This lubrication can be accomplished by the following methods:

1. Mechanical lubricators installed in the track.
2. Mechanical flange lubricators on locomotives.
3. Mechanical lubricators on locomotives applying lubricant directly to the rail.
4. Manual lubrication of rail.

CURVES SHOWING RAIL WEAR BEFORE AND AFTER OILING
100# CARBON RAILS


NOTE- ONE DIVISION (←→) REPRESENTS 1 MONTH OF SERVICE.
ALL RAILS NOT ACCOMPANIED BY THE SIGN (↑)
ARE UNOILED, BUT INCLUDED IN THE AVERAGE.
PERCENTAGES ARE BASED ON HEAD AREA.
2 ND CONTOUR
1 ST. CONTOUR
INSTALLATION OF OILER
DEGREE OF CURVE
RATE
RAIL NUMBER
ABRASION IN PERCENT
CURVES OF VARIOUS RAILS UNDER OBSERVATION
AV. RATE UNOILED 441.7%
AV. RATE OILED 172.7%
AVERAGE RATE OF ABRASION PER MONTH OF SERVICE.
ASSUMED MAXIMUM → 25%
RATE PER YEAR UNOILED 5.292%
RATE PER YEAR OILED 2.064%
RATE PER YEAR 1.5924
LIFE SPAN IN YEARS


CURVES SHOWING RAIL WEAR BEFORE AND AFTER OILING
130# CARBON RAILS
NOTE- ONE DIVISION (→ ←) REPRESENTS 1 MONTH OF SERVICE
ALL RAILS NOT ACCOMPANIED BY THIS SIGN (↑) ARE
UNOILED, BUT INCLUDED IN THE AVERAGE
UNLESS INDICATED OTHERWISE.
PERCENTAGES ARE BASED ON HEAD AREA
ABRASION IN PERCENT
RAIL NUMBER
RATE
DEGREE OF CURVE
INSTALLATION OF OILER
1ST CONTOUR
2ND CONTOUR
130# HEAD FREE RAILS
NOT INCLUDED IN AVERAGE
CURVES OF VARIOUS RAILS UNDER OBSERVATION
AVERAGE RATE UNOILED 2.97%
AVERAGE RATE OILED 1.13%
.0615 (AS OF AUG 1930)
AVERAGE RATE OF ABRASION PER MONTH OF SERVICE
ASSUME MAXIMUM 25%
RATE PER YEAR UNOILED 3.48%
RATE PER YEAR OILED 1.356% (AS OF AUG. 1930)
RATE PER YEAR 978 (AS OF MCH 1931.)
SPAN OF LIFE IN YEARS

In addition to increasing the life of rail on curves, lubrication accomplishes the following:

1. Decreased locomotive driver and wheel flange wear.
2. Longer service life of ties because of decreased gaging.
3. Decreased resistance to train movement.

The economic justification of lubrication depends upon the annual saving resulting therefrom as compared with total annual cost of the lubrication.

It is recommended that the conclusion be adopted for publication in the Manual.

Method of Determining Annual Cost of Lubricator in Track

Total Annual Cost = F + k w
Where F = interest, depreciation, maintenance inspection and repair parts.

Interest on cost of lubricator, $350 at 5 percent	$17.50
Depreciation for 10 years at 7.95 percent	27.83
	$45.33
Labor—maintenance and inspection	16.00
Repair parts	10.00
F =	$71.33

Annual Cost = 71.33 + k w
in which w = wheels over one rail daily, and k = a constant, or annual cost, based on amount of grease used and labor of charging and minor adjustments, per wheel on one rail, which, based on a study by one manufacturer, = $0.02.

Based on 14 trains per day of 60 cars including power = 3,360 wheels daily on one rail.

Annual Cost = 71.33 + 0.02 (3,360) = $138.53

Basic data on lubricator at assumed cost of $350

Cost of new lubricators in place $360

Annual cost

Interest on $360 at 6 percent	$21.60
Depreciation at 20 percent	72.00
Labor—70 hours at 40 cents	28.00
*Grease 1,600 lb. at 2 cents (80 million tons over rail)	32.00
Total annual cost	$153.60

Service records indicate

1 = Unoiled rail receives 2 times flange wear of oiled rail.
2 = Curve length over which oiler is effective—Curves 3 to 6 deg. 1 Mile.

As oiling doubles the life of rail, the necessity for renewal is decreased 50 percent and the annual saving in money brought about by the use of a lubricator may be determined by the formula:

$$\text{Annual Saving} = \frac{0.5\ (C \times D)}{L} - M$$

C = Cost of renewing in kind rail in one mile of track (both rails)
D = Curve length in miles over which oiler is effective
L = Average life of unoiled rail in years
M = Annual cost of lubricator

Cost of renewing rail in kind

	New	*Second hand*
1 ton	$43	$18
Credit	18	10
Net for rail	$25	$ 8
Other track material after credits	16	5
Labor laying	6	6
Total	$47	$19

Cost of renewing rail per mile of track

	152 lb.	*131 lb.*	*130 lb.*	*100 lb.*
New	$11,288	$9,654	$9,602	$7,384
S. H.	4,446	3,819	3,800	2,926

Curves lubricated need not be continuous.

* Grease cost varies from $0.02 to $0.05. This is simply an example to be used as a guide.

Economy of Lubricators

New rail at $40 per ton, scrap credit $10 a ton, leaving a value of $30 per ton to be expended in service.

Of this $20 is used up on the high side.

. $10 is used up on the low side.

Cost of Rail

Tons of new rail $\times$ $20= usable value of rail on high side which can be affected by oiling.

From this last equation we can determine the annual cost of the rail unoiled, either by dividing the value by years if we ignore interest, or from an annuity table if we wish to consider interest.

Cost of Oiling

1 Type of oiler $350	
Depreciation and repairs 10 percent	$35.00
Oil 900 lbs. at 4.48 cents	40.00
Annual cost of one oiler	$75.00

and $75 $\times$ number of oilers = total annual oiling costs.

Cost of oiled rail = (ignoring interest)

Tons of rail $\times$ $20 divided by life in years on high side plus $75 $\times$ number of oilers.

Example—1 mile of 131-lb. rail.

Cost of unoiled rail = 5,280 lin. ft.—103 tons $\times$ $20 = $2060

Annual cost $= \frac{2060,}{Y}$ where Y= life in years.

Oiled rail = using two oilers

5,280 lin. ft. = 103 tons $\times$ 20 = $2060

Annual cost $= \frac{2060}{Y} \times \$150$

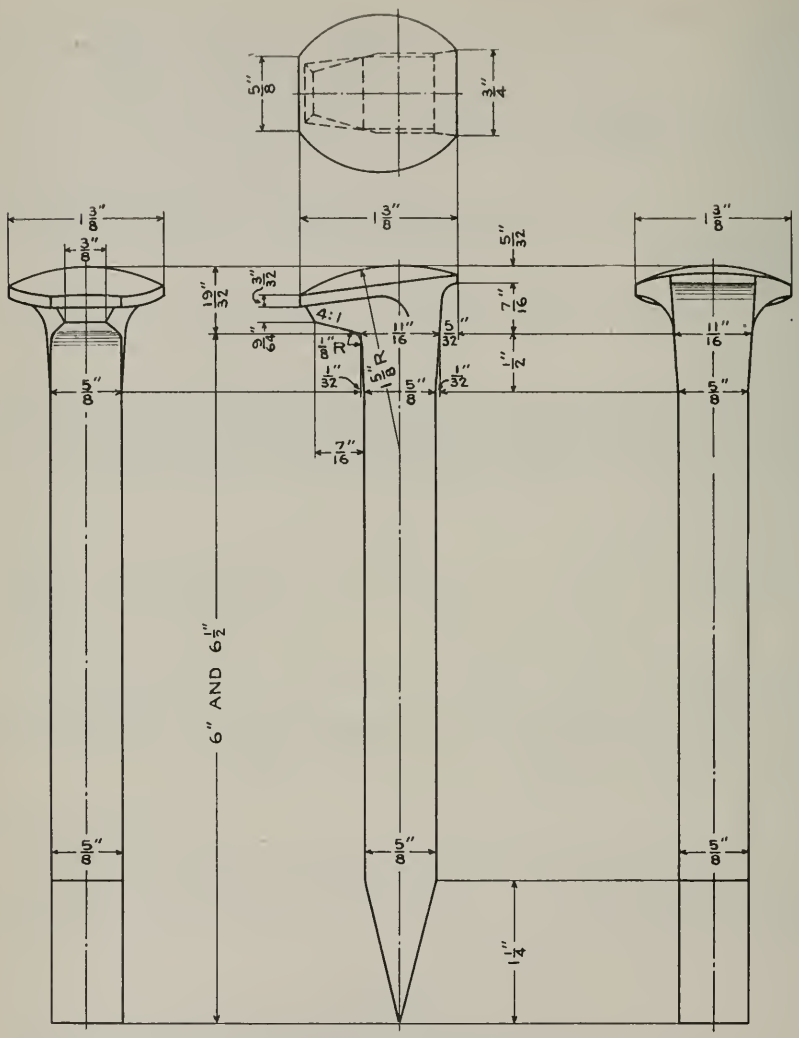
Where Y = life of high rail in years.

Appendix J

(11) DESIGN OF CUT TRACK SPIKES FOR USE WITH AREA TOELESS JOINT BARS

E. W. Caruthers, Chairman, Subcommittee; L. H. Bond, H. F. Fifield, J. de N. Macomb, W. L. Roller.

Difficulty is encountered in driving the present standard cut track spike in the usual position at joints, especially in designs standing well out from the web of the rail. The length of spike head is such that if driven in the usual position the spike must be bent back away from the rail, which is not desirable. The only other method is to reverse the spike and drive it with the heel toward the joint bars. Driven in this position the spike offers very little holding power for lifting the tie when track is being surfaced or joints are picked up. Generally the joint tie does not come up with the rail, making



Design of Cut Track Spike for Use with AREA Toeless Joint Bars.

necessary an extra operation of nipping up the tie. To overcome this difficulty a spike with a shorter head for use at rail joints was reported on last year. This spike is readily manufactured in standard spike machines and is in use on several roads.

While originally suggested for use at rail joints and the subject was so assigned, further consideration by the committee leads to the conclusion that the spike is well adapted to general use. Therefore, the committee now offers the short headed spike in two lengths, 6½ in. and 6 in., for general use.

It is recommended that the plan for the short headed spike shown here be adopted as an alternate standard and incorporated in the Manual.

Appendix K

(12) PREVENTION OF BRINE DRIPPINGS ON TRACK STRUCTURES, COLLABORATING WITH MECHANICAL DIVISION

W. G. Arn, Chairman, Subcommittee; C. W. Baldridge, R. W. E. Bowler, H. R. Clarke, F. W. Hillman, T. T. Irving, C. T. Jackson, W. A Murray, I. H. Schram, G. L. Sitton, C. R. Strattman, Dr. Hermann von Schrenk, J. G. Wishart.

On November 1, 1937 a chemical engineering concern suggested to the Association of American Railroads the addition of strontium chromate to brine in refrigerator cars, for the purpose of protecting track and bridge structures from the resultant damage due to corrosion from brine drippings. Strontium chromate is an oxidizing agent which, it was claimed, would form an oxide film over the steel, thus protecting it against further attack from brine drippings. The chairman of the Engineering division suggested that laboratory tests to substantiate or disprove the claims advanced should be carried out, and proposed that the matter be handled by Subcommittee 12 of the Track committee and appropriate representatives from the Mechanical division. Accordingly, a joint committee consisting of the members of Subcommittee 12 of the Track committee and four representatives from the Mechanical division was appointed to give this matter full consideration. A meeting of this joint committee was held in New York on December 9, 1937, at which meeting a representative of the chemical engineering concern presented information and opinions on the value of strontium chromate as an inhibitor of corrosion from brine drippings. A second meeting was held in Chicago, January 20, 1938, at which meeting the matter was fully discussed. Mr. K. F. Nystrom, mechanical assistant to chief operating officer, Chicago, Milwaukee, St. Paul & Pacific Railroad, presented the results of tests made in the Milwaukee laboratory with inhibitors other than strontium chromate which showed promise of benefits. A number of questions were brought up regarding the use or value of strontium chromate as an inhibitor, and it was decided that laboratory tests should be carried out to determine these various points. A subcommittee of seven members was appointed to draw up the test program and arrange for the tests to be carried out.

Through the courtesy of the respective railroads, the laboratory facilities of the Milwaukee, the Chesapeake & Ohio, and the Denver & Rio Grande Western railroads were placed at the disposal of the subcommittee. A plan of laboratory tests was developed for the purpose of determining the following information which had been requested by the joint committee members regarding the use of strontium chromate as a rust inhibitor:

1. The effectiveness of strontium chromate in inhibiting corrosion of steel from brine drippings.
2. The protective effect of other chemicals in inhibiting corrosion of steel from brine drippings.
3. Whether strontium chromate if added to brine drippings would also afford protection against corrosion of steel from coal drippings.
4. Whether strontium chromate if added to brine drippings would be equally effective on surfaces already coated with rust.
5. Whether strontium chromate would be equally effective for various percentages of salt concentration.
6. Whether strontium chromate, if in very dilute quantities, would tend to accelerate the corrosive action of brine drippings.

As a matter of additional interest, tests were also planned to determine information upon the following two points:

7. The value of copper-bearing steel in resisting corrosion from brine drippings.

8. The value of so-called cathodic protection of steel against corrosion from brine drippings by maintaining an electric charge on the steel which would be opposed in direction to the normal flow of current during electrolytic action.

Fig. 1 shows a typical set-up of the laboratory apparatus used to carry out the tests. The specimens at each laboratory were all taken from the same piece of steel with the exception of the copper-bearing specimens. Th brine drippings were released from the burettes in the amount of 0.5 cc. twice daily, unless otherwise noted. Twice each week the specimens were washed with a specified amount of distilled water to simulate the effects of

Fig. 1.—Typical Apparatus Used in Brine Drippings Tests.

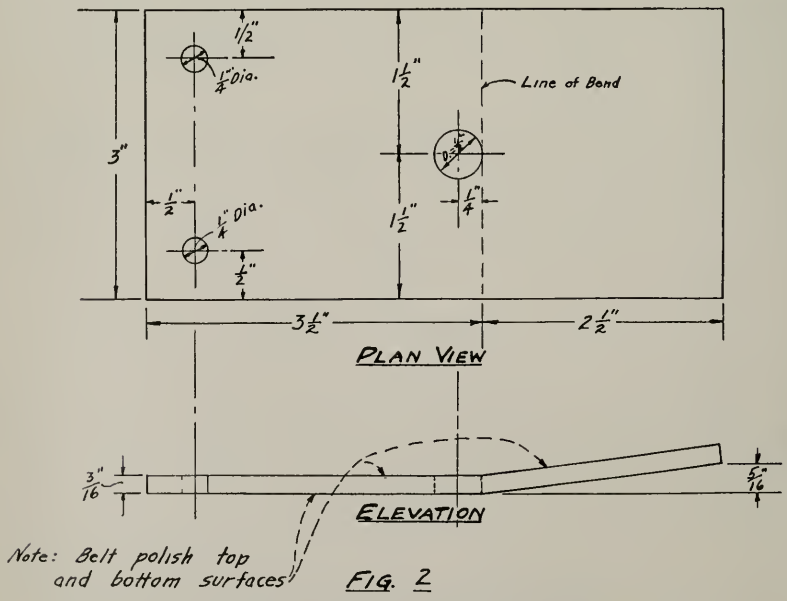


Fig. 2.—Test Specimen for Corrosion from Brine Drippings Tests.

rain. Tests were made for a 30-day period, followed by additional 30-day periods as a check upon the results of the first period. The amount of metal lost by corrosion was determined from the weights of the specimens before tests and following the tests with the rust removed by an approved process.

The test specimen used is shown in Fig. 2. That portion of the specimen upon which the drip fell was inclined, because it was claimed that strontium chromate would afford protection where most of the drippings drained off, whereas more soluble chemicals would not; the theory being that some deposition of salt would occur before drainage, and strontium chromate, being highly insoluble, would also be deposited and thus afford protection. A hole was drilled in each specimen to permit the brine drippings to run underneath, because test results submitted by Mr. C. J. Geyer from the C & O laboratory showed that strontium chromate afforded better protection to the top surface of the test specimen than to the under side. The specimens were placed on a creosoted wood support, as tie plates would be in track.

The results of the tests made to determine each of the points previously stated are as follows:

1. Effectiveness of Strontium Chromate as an Inhibitor of Corrosion from Brine Drippings

Milwaukee Laboratory Tests with Saturated Salt Solution

Specimen No.	Corrodant	Loss in Weight (Grams) 1st Period 31 Days	2nd Period 39 Days	Total 70 Days
1	Distilled water only	0.205	0.452	0.657
2	Saturated salt solution only	0.632	1.105	1.737
4	Saturated salt solution plus strontium chromate	0.365	1.705	2.070

It should be noted that in the above tests the holes were drilled in the test specimen only for the second test period. These holes permitted the brine to contact the under side of the specimen producing more corrosion than when confined to the top surface only. A higher temperature and humidity also prevailed during the latter period.

C & O Laboratory Tests with 5 Percent Salt Solution

Specimen No.	Corrodant	Average Annual Penetration of Corrosion in Inches 1st Period 30 Days	2nd Period 30 Days	Total 60 Days
1	Distilled water only	.00829	.01347	.02176
2	5 percent salt solution only	.02124	.03731	.05855
4	5 percent salt solution with strontium chromate (1 gram/liter concentration)	.02539	.03420	.05959
5	5 percent salt solution with strontium chromate (2 grams/liter concentration)	.02383	.03264	.05647
6	5 percent salt solution with strontium chromate (saturated solution — grams per liter)	.02435	.02694	.05129

It will be noted that the results of the tests from both laboratories indicate no appreciable benefit from the addition of strontium chromate in inhibiting corrosion from the brine drippings.

A

2. The Value of Other Chemicals as an Inhibitor of Corrosion from Brine Drippings

Milwaukee Laboratory Tests with Saturated Salt Solution

Specimen No.	Corrodant	Loss in Weight (Grams) 1st Period 31 Days	2nd Period 39 Days	Total 70 Days
1	Distilled water only	.205	.452	.657
2	Saturated (26.5 percent) salt solution only	.632	1.105	1.737
7	Saturated salt solution plus ½ percent soda ash	.194	.958	1.152
8	Saturated salt solution plus 1 percent soda ash	.150	.797	.947
9	Saturated salt solution plus ½ percent sodium hydroxide	.128	.336	.464
10	Saturated salt solution plus 1 percent sodium hydroxide	.169	.536	.705
11	Saturated salt solution plus sodium bichromate (5 grams per liter concentration)	.184	.357	.541
3R	Saturated salt solution plus sodium silicate (Rusticon C) saturated solution	.048	.387	.435

Attention is again directed that, in the second period of tests, holes were provided in the test specimen which resulted in increased corrosion on the under side of the specimen.

C & O Laboratory Tests with 5 Percent Salt Solution

Specimen No.	Corrodant	Average Annual Penetration of Corrosion in Inches 1st Period 30 Days	2nd Period 30 Days	Total 60 Days
1	Distilled water only	.00829	.01347	.02176
2	5 percent salt solution only	.02124	.03731	.05855
7	5 percent salt solution plus ½ percent soda ash	.02539	.03523	.06062
8	5 per cent salt solution plus 1 percent soda ash	.01969	.02850	.04819
9	5 percent salt solution plus ½ percent sodium hydroxide	.02176	.02798	.04974
10	5 percent salt solution plus 1 percent sodium hydroxide	.02124	.02798	.04922
11	5 percent salt solution plus 5 grams sodium bichromate per liter	.02021	.03057	.05078
12	5 percent salt solution plus 5 grams zinc chromate per liter	.02228	.03057	.05285
13	5 percent salt solution plus zinc chromate, saturated concentration	.01399	.01710	.03109
17	5 percent salt solution plus sodium silicate (Rusticon C) saturated solution	.02072	.....	.....

It will be noted from the above test results that the Milwaukee tests shows less corrosion with saturated salt solution plus ½ percent sodium hydroxide, with sodium bichromate, and with the sodium silicate than occurred with the distilled water only. The results of the C & O laboratory tests showed benefits from these chemicals, but relatively much less in extent. The 5 percent salt solution saturated with zinc chromate showed the best protection.

3. The Effect of Strontium Chromate Added to Brine Drippings in Affording Protection Against Corrosion of Steel From Coal Drippings

Milwaukee Laboratory Tests with Saturated Salt Solution

Specimen No.	Corrodant	Loss in Weight (Grams) 1st Period 31 Days	2nd Period 39 Days	Total 70 Days
15	0.5 cc. coal drippings each morning	.223	.403	.626
Est.	0.5 cc. coal drippings each morning with ½ of corrosion from saturated salt solution test added	.539	.955	1.494
14	0.5 cc. saturated salt solution plus saturated strontium chromate each evening 0.5 cc. coal drippings each morning	.417	.800	1.217

C & O Laboratory Tests with 5 Percent Salt Solution

Specimen No.	Corrodant	Average Annual Penetration of Corrosion in Inches 1st Period 30 Days	2nd Period 30 Days	Total 60 Days
15	Coal drippings 0.5 cc. each morning.....	.00984	.01399	.02383
Est.	Coal drippings 0.5 cc. each morning with ½ of corrosion from 5 percent salt solution test added	.02546	.03265	.05812
14	5 percent salt solution plus strontium chromate (2 grams per liter) 0.5 cc. evenings Coal drippings—0.5 cc. mornings	.02642	.03420	.06062

The above results show that the additional application of the brine drippings in the evenings, even though containing strontium chromate in solution, resulted in a material increase in corrosion over that from brine drippings alone. Since brine drippings were not applied in the mornings on the test of Specimens 15, an estimate has been made of the corrosion that would have occurred had this been done by adding to the corrosion loss of these specimens, one-half the corrosion loss on the specimens where the salt solution only was applied. These results indicate no appreciable benefit from the strontium chromate.

4. The Effect of Strontium Chromate Added to Brine Drippings on Surfaces Already Corroded

C & O Laboratory Tests with 5 Percent Salt Solution

Specimen No.	Corrodant	Average Annual Penetration of Corrosion in Inches 1st Period 30 Days	2nd Period 30 Days	Total 60 Days
3	5 percent salt solution on prerusted specimen	.02798	.05544	.08342
16	5 percent solution plus strontium chromate (2 grams per liter) on prerusted specimen	.02591	.05804	.08395

Specimens were prerusted in a weatherometer to secure an uniform amount of corrosion on each. The results indicate no benefit from the strontium chromate.

5. The Effect of Strontium Chromate with Different Percentages of Salt Concentration

It was planned to conduct tests at four railway laboratories with salt concentrations of 5 percent, 10 percent, 15 percent, and "saturated" respectively. However, only two of the laboratories were in position to make the tests, and the salt concentrations of 5 percent and "saturated" were used. The preceding results give the information for these two concentrations and it will be noted that, although the strontium chromate is somewhat more effective for the weaker salt solution, it does not even here afford material benefit.

6. The Effect of Strontium Chromate in Very Dilute Quantities on Inhibiting Corrosion from Brine Drippings

Tests were carried out at the Denver & Rio Grande Western Railway laboratory with strontium chromate in different concentrations. Also, similar tests were carried out using sodium silicate in two forms: lump (Rusticon C) and powdered.

The test specimens were 1 in. x 2 in. and were mounted on a board on a 4:1 slope, in coal tar paint so the back and edges were not subject to corrosive action. One-half ccm of solution was applied to each piece on the morning and evening of each day. The accumulation of salt was washed off each Wednesday and Saturday noon. The tests were carried on for 30 days.

Denver and Rio Grande Western Laboratory Tests

Corrodant	*Inhibitor*	*Concentration of Inhibitor Grams Per Liter*	*Average Annual Penetration In Inches*
Distilled Water	None	....	0.0067
15 percent Salt Solution	None	....	0.0117
"	Strontium Chromate	0.005	0.0125
"	" "	0.01	0.0117
"	" "	0.10	0.0125
"	" "	0.25	0.012
"	" "	0.50	0.0095
"	" "	1.00	0.0024
"	" "	1.50	0.0022
"	" "	2.00	0.0017
"	" "	2.57	0.00016
	Rusticon C	0.065	0.0057
"	"	0.13	0.0093
"	"	0.26	0.0062
"	"	0.52	0.0021
"	"	0.78	0.0016
"	"	1.04	0.0014
"	"	1.30	0.0007
"	Sodium Silicate Compound	0.28	0.0047
"	" (Powdered)	0.56	0.0030
"	"	1.12	0.0026
"	"	2.24	0.0020
"	"	3.36	0.0012
"	"	4.48	0.0011
"	"	5.60	0.0010

The above results show that with very dilute quantities of strontium chromate there is some slight increase in corrosion compared to that with salt solution alone. Of most interest, however, is the marked reduction of corrosion with high concentrations of the

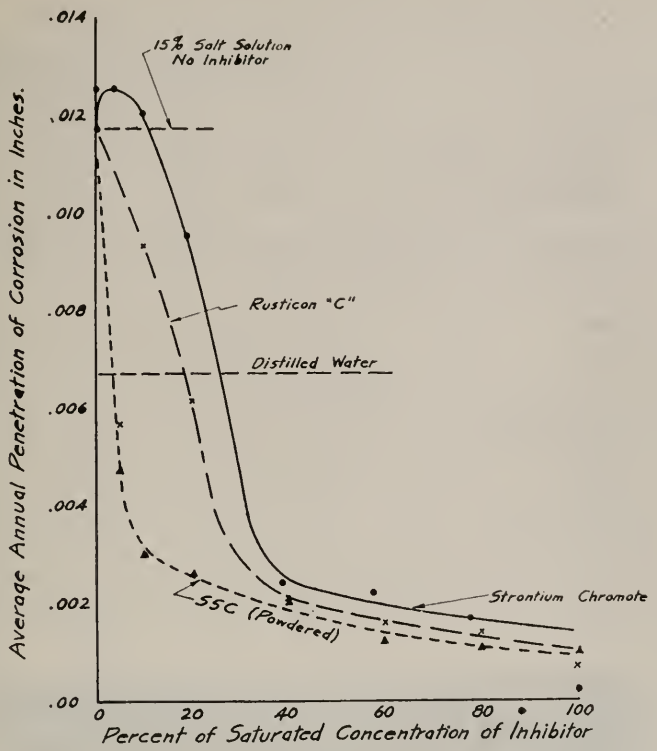


FIG. 3.—Corrosion with Various Concentrations of Inhibitors—Laboratory of Denver & Rio Grande Western.

inhibitor. Inasmuch, as these results seem quite opposed to those from the other laboratories, it can only be concluded that the difference is due to not permitting the salt solution to contact the under side of the specimen in these tests. Additional tests should be made to verify this point.

In Fig. 3 is shown graphically the result of these tests. The superior protection afforded by the sodium silicate (powdered) will be readily noted from these tests.

7. The Value of Copper-Bearing Steel in Resisting Corrosion from Brine Drippings

MILWAUKEE LABORATORY TESTS WITH SATURATED SALT SOLUTION

Specimen No.	*Corrodant*	*Loss in Weight (Grams) 2nd Period 39 Days*
2	Saturated salt solution only	1.105
3T	Saturated salt solution only on copper bearing steel	.797

C & O Laboratory Tests with Saturated Salt Solution

Specimen No.	Corrodant	Average Annual Penetration of Corrosion in Inches 1st Period 30 Days	2nd Period 30 Days	Total 60 Days
2	5 percent salt solution only	.02124	.03731	.05855
C.B.S.	5 percent salt solution only on copper-bearing steel	.02539	.03679	.06218

The foregoing results do not indicate that copper bearing steel is particularly effective in resisting corrosion from brine drippings.

8. The Value of Cathodic Protection Against Corrosion from Brine Drippings

These tests were carried out at the Denver & Rio Grande Western laboratory. The apparatus used is shown in Fig. 4. The test pieces were 1 in. by 2 in. by ⅛ in. made from scrap iron, and were pickled and brushed before the test started. They were mounted on a plank in the box on a 4:1 slope, thus duplicating the slope of a rail base. The box was filled with cinders up to the edge of the plank about ½ in. from the test pieces. A copper strip for the positive terminal was fastened along the side of the plank, about 1½ in. away from the closest portion of the test pieces. Three test pieces were protected by negative current and three test pieces were not. The three protected pieces were wired together at their upper edge, and connected to the negative plates of a rectifier.

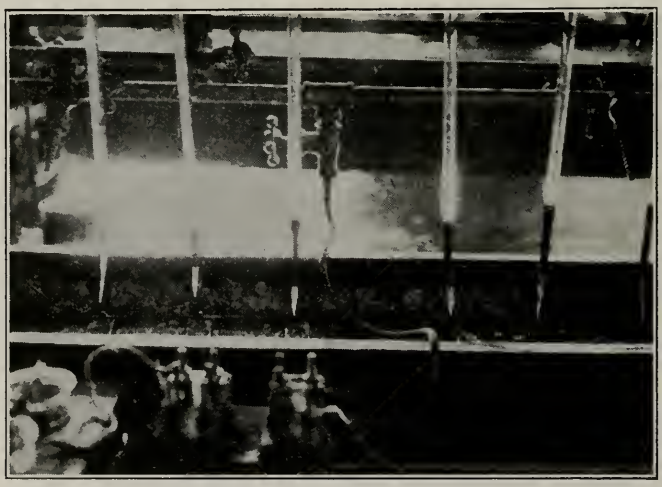


Fig. 4.—Showing Setup of Test Pieces Mounted on a Plank in a Box on a 4:1 Slope. Box Filled with Cinders up to Edge of Plank.

During the test, which ran 10 days, 1 cc. of 15 percent salt solution was applied on each of the six pieces every 20 minutes, making 25 applications per day. The second and ninth days of the test came on Sunday, and no salt was applied. Between applica-

tions, the solution did not dry up except on the upper one-third of the test piece, so that the pieces were nearly completely covered with the conducting solution 8 hours a day. All of the salt deposit was washed off every morning with distilled water. The electric circuit was thus complete as long as the pieces were wet. During the night the rectifier was left on and as the pieces dried out, flow of current dropped off to zero. When pieces become dry, corrosion ceases and protection is not necessary.

The voltage between the test pieces and the positive terminal varied from 6.0 to 3.0 the first three days. On the fourth day it fell to 1.0, and new plates were put in the rectifier. From then till the test was completed, the voltage varied from 6.0 to 3.5. The amperage varied from 0.018 to 0.050, the milliamperes being from 5 to 8 times the voltage. The surprising point of the test is the relatively high protection with such a small current density.

The losses of weight of the pieces are shown in the table.

Specimen	*Loss, Grams*	*Average Annual Penetration Inches*
	Protected Pieces	
1	0.0804	0.0060
2	0.0330	0.0025
3	0.0567	0.0042
Average	0.0567	0.0042
	Unprotected Pieces	
4	0.2808	0.021
5	0.2608	0.019
6	0.2978	0.022
Average	0.2798	0.021

The positive terminal was very severely corroded.

Although this method of protection shows effective results in these laboratory tests, the application of the cathodic protection to the track and bridge structure appears impractical at the present time.

Acknowledgment

The foregoing tests were made possible through the courtesy and with the assistance of Mr. K. F. Nystrom, mechanical assistant to chief operating officer, Mr. H. G. Miller, engineer of tests, and Mr. L. E. Grant, chief chemist of the Chicago, Milwaukee, St. Paul & Pacific Railroad; Mr. C. J. Geyer, engineer maintenance of way, Mr. C. M. Angel, engineer of tests, and Mr. A. S. Perry, chief chemist of the Chesapeake & Ohio Railway; Mr. A. E. Perlman, engineer maintenance of way, Mr. Ray McBrian, engineer of tests, and Mr. Walter Leaf, research technician, of the Denver & Rio Grande Western Railway.

Appendix

Prior to the tests originally described, the Chesapeake & Ohio laboratory conducted a series of tests of rail steel specimens subjected to salt solution with and without strontium chromate content. The apparatus used consisted of an especially constructed spray drip chamber as shown in Fig. 5. Salt solution was sprayed from a nozzle, located in the reservoir, against the roof of the chamber where it collected and dripped upon the test specimen. The test specimen rested on the inclined portion of the chamber floor and was insulated from it by a rubber mat. In one series of tests, a filter tray containing strontium chromate was placed over the specimen so the brine drippings would pass through it and dissolve the inhibitor before contacting the specimen.

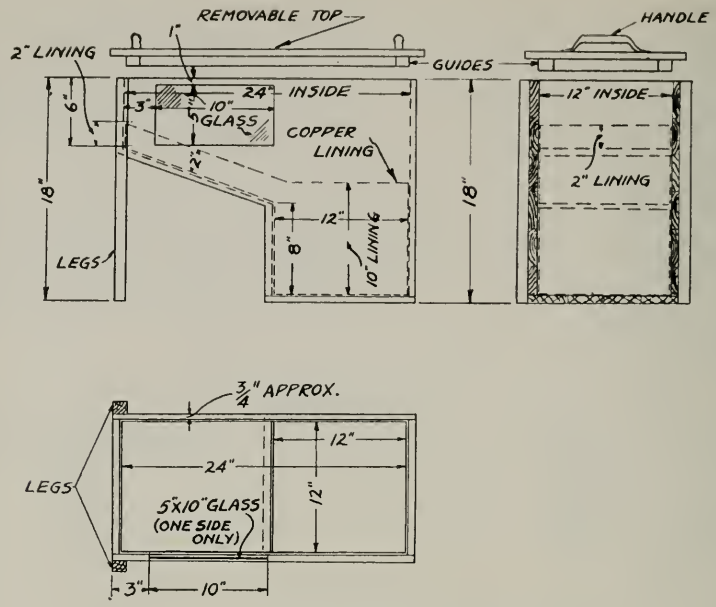


FIG. 5.—Salt Spray Dripping Apparatus.

The results were as follows:

Specimen No.	*Corrodant*	*Loss in Weight Grams*	*Average Annual Penetration of Corrosion in In.*
1	Salt spray drippings filtered through strontium chromate	53.2	0.8999
3	Salt solution plus strontium chromate	36.4	0.6197
5	Salt solution	59.9	1.0155
2	Salt spray drippings filtered through strontium chromate	1.4	0.0608
4	Salt solution plus strontium chromate	1.3	0.0579
6	Salt solution	1.5	0.0646

Specimens 1, 3, and 5 were subjected to a continuous spray of saturated salt solution for 17 days.

Specimens 2, 4, and 6 were subjected to 2 liters of saturated salt solution drippings each 24 hours for 17 days. These specimens were considerably smaller than the other three.

Little benefit from the strontium chromate was shown in these tests. Examination of the test specimens showed that the top surface had been well protected against corrosion by the strontium chromate, but much corrosion and localized pitting occurred on the bottom surfaces.

This report is offered as information with the recommendation that the subject be continued.

REPORT OF COMMITTEE 4—RAIL

JOHN V. NEUBERT, *Chairman;*	A. F. BLAESS, *Vice Chairman;*	LOUIS YAGER, *Vice Chairman;*
J. B. AKERS,	F. W. GARDINER,	J. C. PATTERSON,
JOHN E. ARMSTRONG,	F. M. GRAHAM,	W. H. PENFIELD,
W. J. BACKES,	G. W. HARRIS,	P. PETRI,
M. M. BACKUS,	B. HERMAN,	G. A. PHILLIPS,
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H. R. CLARKE,	G. M. MAGEE,	J. C. WALLACE,
W. A. DUFF,	RAY MCBRIAN,	BARTON WHEELWRIGHT,
ROBERT FARIES,	WM. MICHEL,	J. E. WILLOUGHBY,
J. M. FARRIN,	C. E. MORGAN,	W. P. WILTSEE.
ROBERT H. FORD,	E. E. OVIATT,	*Committee.*

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. (a) Further research, including details of mill practice and manufacture as they affect rail quality and rail failures, giving special attention to transverse fissure failures, and other defects in the head, web and base, collaborating with Rail Manufacturers' Technical Committee (Appendix B). Progress report.

(b) Specifications for thermal treatment of rail (such as controlled cooled, Brunorized, etc.) (Appendix B). Progress report.

3. Compilation of Statistics.

(a) All rail failures, making special study of transverse fissure failures (Appendices C and D). Progress reports.

(b) Compilation of statistics for determining the performance of controlled cooled and Brunorized rail in service with respect to rail failures, with the view toward evaluating the higher price paid for treated than untreated rails (Appendix E). Progress report.

4. Cause and prevention of rail battering and methods of reconditioning rail ends, fastenings, and frogs in track (Appendix F). Progress report.

5. Economic value of different sizes of rail (Appendix G). Progress report.

6. Economics of rail lengths in excess of 39 ft. (Appendix H). Final report.

7. Continuous welding of rail, collaborating with Committee 5—Track and Special Committee on Stresses in Railroad Track (Appendix I). Progress report.

8. Service tests of various types of joint bars (Appendix J). Progress report.

9. Investigate the advisability of straightening bent and kinked rails for reuse in main line (Appendix K). Final report.

10. Specifications for relayer rail (Appendix L). Final report.

THE COMMITTEE ON RAIL,
JOHN V. NEUBERT, *Chairman.*

Bulletin 409, February, 1939.

Herbert S. Clarke

Herbert S. Clarke, engineer maintenance of way, Delaware & Hudson Railroad, Albany, N. Y., a member of Committee 4—Rail, died on June 25, 1938.

A native of Ontario, Mr. Clarke was educated in the School of Practical Science of the University of Toronto, and was employed in engineering work in Canada for some 15 years before entering the service of the Delaware & Hudson as division engineer. The training he received in these earlier years of his career, during which he was employed in railroad location, construction and maintenance, served him well in his work with the Delaware & Hudson.

Being advanced subsequently to engineer maintenance of way, he received wide recognition for his pioneer work in the continuous welding of rail and for his administration of a forward-looking policy in the organization of maintenance forces. Because of these professional attainments, as well as for his estimable personal qualities, Mr. Clarke was a highly esteemed member of this committee.

He was a member of the American Railway Engineering Association since 1920. He served on Committee 9—Highways (Grade Crossings at that time) in 1927, and also on Committee 5—Track for two years, 1930–1931.

The Committee on Rail wishes to record here its appreciation of his many estimable qualities and the profound regret occasioned by his death.

JOHN V. NEUBERT, *Chairman.*

Asa H. Morrill

Asa H. Morrill, Chief Engineer of the Boston & Maine Railroad, the Maine Central Railroad, and the Portland Terminal Company, died on December 20, 1938.

Mr. Morrill was born in Concord, N. H., on October 7, 1870, and was graduated from the Massachusetts Institute of Technology in the Class of 1892. He immediately entered railroad service as assistant engineer of the Buffalo, Rochester & Pittsburgh Railroad. Later in the same year he was named assistant engineer of the New York, New Haven & Hartford Railroad. In 1898 he became associated with the contracting firm of Charles McDermitt, as superintendent, but shortly afterward he returned to the service of the New Haven's engineering department. He entered the service of the Maine Central in 1907 as engineer of construction and in 1928 was named chief engineer of that road.

In April, 1933, he took on added duties of assistant chief engineer of the Boston & Maine Railroad, and in 1936 was promoted to acting chief engineer of both the Boston & Maine and the Maine Central. He was named chief engineer of both roads, and also of the Portland Terminal Company on July 13, 1936, which position he held until his death.

Mr. Morrill became a member of the American Railway Engineering Association in April, 1928, and in addition to his participation in the work of the Committee on Rail, of which he was a member from 1937 to 1939, he was a member of the Committee on Buildings from 1928 to 1936, and the Special Committee on Waterproofing from 1932 to 1934.

The Committee on Rail wishes to record here its appreciation of his many estimable qualities, and the profound regret occasioned by his death.

JOHN V. NEUBERT, *Chairman.*

James Bertram Young

James Bertram Young, engineer of tests of the Reading Company, Reading, Pa., a member of Committee 4—Rail, died on July 29, 1938.

Mr. Young was born at Philadelphia, Pa., on May 27, 1876, being educated at William Penn Charter School and the University of Pennsylvania, from which he was graduated with a bachelor's degree in chemistry. Following his chosen field, he became assistant chemist of the Philadelphia & Reading (now the Reading) in 1898, was advanced to chief chemist in 1906, and received further recognition in 1920 by promotion to engineer of tests.

Becoming a member of the American Railway Engineering Association in 1920, he was assigned immediately to the Committee on Rail, which committee he served faithfully until the time of his death. Thoroughly imbued with the scientific point of view and given to a thorough study of problems presented to him, his work and counsel were valued highly by his associates on the committee.

The Committee on Rail wishes to record here its appreciation of his many estimable qualities and the profound regret occasioned by his death.

John V. Neubert, *Chairman.*

Edward L. Bahls

Edward L. Bahls, a member of the American Railway Engineering Association and office engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, died suddenly in his home in Chicago, Illinois, on October 27, 1938. It was a great shock to us to learn of his untimely passing when we recalled that but three days before his death he had met with our subcommittee representing Mr. W. H. Penfield in our meeting with the staff of the Rails Investigation at the University of Illinois. His pleasing personality and conscientious devotion to his duties won the esteem and respect of his associates, who deeply feel his loss.

Subcommittee No. 1, Committee on Rail.

Appendix A

(1) REVISION OF MANUAL

Louis Yager, Chairman, Subcommittee; A. F. Blaess, J. E. Armstrong, W. C. Barnes, N. J. Boughton, C. B. Bronson, E. E. Chapman, W. A. Duff, F. M. Graham, G. W. Harris, Maro Johnson, B. R. Kulp, A. H. Morrill, John V. Neubert, E. E. Oviatt, W. H. Penfield, C. P. Van Gundy.

Subject No. 1—Revision of Specifications for Heat Treated Carbon Steel—Alloy Steel Track Bolts 1936 Manual 4–29. For the purpose of clarification and to conform our specifications to the ASTM revisions we propose the following changes:

Present

Chemical Composition Section 3(b). The steel for the nuts shall conform to the screw steel grades of the ASTM specifications for commercial quality, hot-rolled bar steel, Serial Designation, A–107, latest issue.

Proposed

(b) The steel for the nuts shall conform to resulphurized nut stock grade of the ASTM specifications for commercial quality, hot-rolled bar steel, Serial Designation A–107, latest issue.

Present

Strip Test—Section 9. The threads of the nut must not "strip" when the bolt, with nut fully mounted, is tested in tension to its yield point, the load being applied to the head of the bolt and the bearing side of the nut.

Proposed

The threads of the nut shall not "strip" when the bolt, with the nut fully mounted, is tested in tension to the minimum yield point specified in Section 6(a) for the grade ordered, based on the theoretical area at the root of the thread, the load being applied to the head of the bolt and the bearing side of the nut.

Subject No. 2—Revision of Specifications for Open Hearth Steel Rails—1937 Manual page 4–1, to include Every-Ingot Nick and Break Test. The rail manufacturers through their authorized representatives have offered to accept, without increase in the base price, the inclusion of the Every-Ingot Nick and Break Test for the definite identification of "X-Rayls" in the "A" rails, and we recommend the adoption.

Present

Elongation and Permanent Set—Section 302(a). One of the three test specimens shall be given a sufficient number of blows to determine, for information only, the exhausted ductility, reported inch by inch over the entire six inches gaged. No ductility readings will be taken between blows. The other two specimens shall be nicked and broken. The fracture of each specimen shall be examined to determine the requirements of Section 303.

Interior Condition, Section 303. If the fracture on any test specimen exhibits seams, laminations, cavities, interposed foreign matter or a distinctly bright or fine grained structure, all the top rails represented shall be classified as "X-Rayls".

Proposed

302. Elongation and Permanent Set

(a) One of the three test specimens shall be given a sufficient number of blows to determine, for information only, the exhausted ductility, reported inch by inch over the entire six inches gaged. No ductility readings will be taken between blows.

303. Interior Condition

A test piece representing the top end of the top rail of each ingot of each heat rolled, which has passed the drop test requirements of Section 301 shall be nicked and broken. If the fracture on any test specimen exhibits seams, laminations, cavities, interposed foreign matter, or a distinctly bright or fine grained structure, the top rail represented shall be classed as an "X-Rayl".

This committee has been requested by a number of railroads, as well as by the Rail Manufacturers' Technical committee, to make a recommendation in connection with the slotting and beveling of the ends of rail on account of the differences in so many of the railroads' specifications, and these differences being so very slight. The committee has given this very careful thought and consideration and it recommends the acceptance of the slotting and beveling similar to that shown on Track Committee's AREA Plan No. 140, which is a horizontal back cut of $\frac{1}{16}$ in. and a depth of $\frac{1}{8}$ in., and this is the same as submitted by the Track committee and adopted at the Convention in 1938.

The committee also recommends that the following note "Spike may be driven as shown, or reverse" be added to Plan 411—Joint Bar and Assembly for 112-lb. R.E. Rail, and to Plan 412—Joint Bar and Assembly for 131-lb. R.E. Rail, which now appear in the Manual as pages 4–27 and 4–28 respectively.

Appendix B

(2) (a) FURTHER RESEARCH, INCLUDING DETAILS OF MILL PRACTICE AND MANUFACTURE AS THEY AFFECT RAIL QUALITY AND RAIL FAILURES

Giving Special Attention to Transverse Fissure Failures and Other Defects in the Head, Web and Base, Collaborating with Rail Manufacturers' Technical Committee

and

(b) SPECIFICATIONS FOR THERMAL TREATMENT OF RAIL (Such as Controlled Cooled, Brunorized, Etc.)

John V. Neubert, Chairman, Subcommittee; J. E. Armstrong, W. C. Barnes, A. F. Blaess, C. B. Bronson, E. E. Chapman, Robt. Faries, P. Petri, W. P. Wiltsee, Louis Yager.

RAILS INVESTIGATION

Work Done During 1938

1. Fourth Progress Report

This summary of work for the past year covers only the general lines of the study and results. Fuller details of the progress of the investigation from March, 1937, to March, 1938, are given in the report of March, 1938, and published in the 1938 Proceedings of the AREA, page 807.

2. Temperature Limits for Controlled Cooling of Rails

In the Fourth Progress Report details of the first mill study of temperature limits for controlled cooling of rails were reported. This first study was made at the Ensley plant of the Tennessee Coal, Iron and Railroad Company at Birmingham, Ala. Since the publication of that report tests have been completed and the results tabulated for a second test made at the works of the Dominion Steel and Coal Corporation, Ltd., Sydney, Nova Scotia. In this second test rails produced by the ordinary process were studied, and there were also studied rails rolled from three ingots through which hydrogen had been passed while the steel was in the molten state. The use of hydrogen in this test was to insure the presence of shatter cracks in ordinary hot-bed cooled rails. It was highly successful for this purpose.

A third test has been made at the works of the Carnegie–Illinois Steel Corporation, Gary, Ind. Here too, studies were made on normally produced rails and on rails from ingots which were treated with hydrogen. The results from these three tests indicate that with adequate controlled cooling the prevention of shatter cracks in rails is assured. The tests so far made indicate that the present standards for control-cooled rails are somewhat conservative, both as to time and temperature range in the cooling boxes. However, it has not been thought wise so far to suggest a definite change in the present specifications.

3. Metallographic and Hardness Tests of End-Hardened Rails

These studies of end-hardened rails have been continued and a considerable amount of data obtained. In connection with service records and end-batter tests, there are indications of a lower limit of Brinell (or Rockwell "C") hardness below which the end hardening is not very effective in preventing batter. This lower limit is somewhere in the vicinity of 320 Brinell (34 Rockwell "C").

4. Mechanical Tests of Specimens from End-Hardened Rails

The gathering of data on the properties of the hardened steel in end-hardened rail has been continued, and a study of the variation of mechanical properties with varying hardness produced by heat treatment is in progress. There seems to be some indication that if hardening is carried higher than Brinell 450 (about 48 Rockwell "C") there is danger of a loss of toughness (energy for fracture) in the rail steel which would seem to over-balance the gain due to increased strength.

5. Rolling-Load Tests of Batter of Rails

The rolling-load tests of batter of rails have been continuously in progress and the rolling-load tests show distinctly the reduction of batter by end-hardening processes producing hardness above about Brinell 320 (34 Rockwell "C"). So far differences in the reduction of batter by various end-hardening treatments do not seem to be sufficient to be measured accurately by present test methods.

6. Preparation for Field Tests of Batter

Apparatus for the field measurement of batter has been constructed, and a portable Brinell hardness machine is nearly completed. This machine has been designed by Professor H. R. Thomas of the test party, and it uses the same method of load measurement as do the standard laboratory Brinell machines. Its total weight is about 25 lb., due to a free use of duralumin in its framework. The test party, so far as can be seen, will be ready to go to work on the field tests of batter as soon as test rail is laid.

7. Non-Destructive Tests

The vibration tests of rails showed sufficient promise of a test which would indicate shatter cracks in new rails to justify the building of a somewhat more powerful apparatus. This has now been constructed and a few preliminary results have been obtained. (Note: It is hoped to make a fuller report of this process in the next progress report of this investigation). The progress of these vibration tests has been retarded by the necessity of occasional trips to witness detector-car runs over test track.

8. Failure of Test Rails in Track

Representatives of the investigation have been present at detector-car tests at various locations of test track laid in the early part of the investigation. Since our last progress report, two horizontal and one transverse fissure have been found in 130-lb. rails laid near Kearneysville, W. Va. on the Baltimore & Ohio Railroad.

9. Bend Tests for Rails

A short series of special tests on sound rails has been carried out to study the effect of variation of span and of cross-section of rail on the results of bend tests. It is planned to present these results in the next quarterly report. In this connection a subcommittee of the AREA Rail committee met at the University of Illinois and discussed the question of bend tests for rails. It is not felt that without special authorization the Rails Investigation can do more than make these few preliminary tests which may serve as a basis for evaluating tests made under different conditions of span and cross-section of rail.

RAILS INVESTIGATION

Work Planned for 1939

1. Study of Temperature Limits for Control-Cooled Rails

So far the studies of temperature limits for control-cooled rail have been made on rails placed in the cooling boxes at 900 deg. F. and at 500 deg. F. It seems desirable that tests should be made on rails placed in the cooling boxes at 700 deg. F. It also seems highly desirable to make tests of the rates of cooling of rails in different layers of cooling boxes or tanks used at one or more steel mills, since no information of the extent of such variations of cooling rate has come to the attention of the test party. The temperature recording apparatus used in previous tests can be used in this study of cooling rates in mill cooling boxes. This study of actual variations in rates of cooling seems highly desirable before the consideration of modifications in present standards is taken up.

2. Field Tests of Batter of End-Hardened Rails

It is hoped that during 1939 the field tests of end-hardened rail may be started. This would be a major activity of the test party and eventually should furnish more authoritative data than that given by the rolling-load batter tests in the laboratory. Rolling-load tests can give an indication of the batter-resistance of the metal in the hardened end of the rail and can suggest hardening methods to be included in the field tests. It cannot predict the *shape* of batter which will be set up by the passage of wheels moving at a very much higher speed than that possible in the rolling-load test. However, it is proposed to continue the rolling-load tests for batter, using different widths of gap between rail ends. This test has become a matter of routine, and rolling-load tests can be carried on with little expense.

3. Other Tests of the End-Hardening Processes

Metallographic studies and tests of specimens from end-hardened rails will continue to be made. These results may be expected to throw light on the nature of the end-hardening process and its effect on the properties of the steel. Studies will be continued on the relation of batter to Brinell (or Rockwell "C") hardness.

4. Bend Tests for Rails

Whether the investigation shall take up the detailed study of the bend test as a possible substitute for the present drop tests on rails depends upon the judgment of the Joint Advisory committee. It has been deemed advisable to make a few preliminary studies, but in any extensive study it would be desirable to make many bend tests at a steel mill with representatives of the test party present. Such bend tests might give direct comparison with routine drop tests. This matter will, of course, have to be decided upon by the Joint Advisory committee of the Rails Investigation. The test party will be ready to proceed with this matter if authorized to do so.

5. Non-Destructive Tests for Shatter Cracks

It is hoped that during the coming year it may be decided whether to abandon this line of study or whether results give sufficient promise to carry it further. If this line is abandoned the work of keeping in touch with the field and detector car tests will, of course, be continued.

6. Miscellaneous Tests

Many testing problems will doubtless arise during the coming year. Two have already been suggested. The first was suggested by the failure of one of the rolling-load specimens of welded rails, which failed not at the weld but at a stamped letter on the web. A study of damage by stamped letters is suggested.

The second problem is that of a study of the damage done by "gagging" rails. It has been suggested that the pieces of rail which have been broken in bend or drop tests would furnish specimens of steel which had been subjected to various degrees of severity of gagging varying from un-gagged steel over the supports of the specimen to steel bent to its ultimate strength at the center of the specimen.

This is submitted as a progress report and it is recommended that the subject be continued.

Appendix C

(3) RAIL FAILURE STATISTICS FOR 1937

By W. C. Barnes, Engineer of Tests, Rail Committee

The rail failure statistics for the year ended December 31, 1937, appearing in this report, have been compiled in accordance with the standard method of basing the failure rates on mile-years of service in track.

The reported tonnages and track miles of rollings for 1932 and succeeding years included in these statistics are as follows:

Year Rolled	*Tons*	*Track Miles*
1932	236,632	1,341
1933	204,789	1,082
1934	636,901	3,430
1935	371,888	2,035
1936	681,520	3,720
Totals	2,131,730	11,608

This compares with totals of 2,217,459 tons, or 12,175 track miles, of rail reported last year for the 1931 to 1935 rollings.

TABLE I - AVERAGE FAILURES PER 100 TRACK MILES - ALL MILLS
(Both service and detected failures are included)

Year Rolled	YEARS SERVICE				
	1	2	3	4	5
1908					398.1
1909				224.1	277.8
1910			124.0	152.7	198.5
1911		77.0	104.4	133.3	176.3
1912	28.9	32.1	49.3	78.9	107.1
1913	12.5	25.8	44.8	69.5	91.9
1914	8.2	19.8	32.9	50.9	74.0
1915	8.9	19.0	34.2	53.0	82.4
1916	11.8	29.2	47.7	70.6	105.4
1917	21.6	38.9	66.0	110.5	137.0
1918	8.9	27.6	54.0	92.8	125.4
1919	14.8	39.4	73.7	104.8	115.7
1920	14.2	32.4	63.1	84.5	119.6
1921	10.9	34.9	56.9	70.9	98.9
1922	15.9	34.8	55.2	80.4	110.0
1923	14.3	33.2	57.6	86.0	114.1
1924	14.0	33.4	58.3	82.0	110.7
1925	15.5	36.6	58.3	76.6	110.7
1926	17.1	41.2	64.6	102.6	131.3
1927	18.4	37.7	69.5	94.6	112.4
1928	11.0	28.0	45.8	57.4	76.4
1929	14.1	36.8	55.9	82.7	121.2
1930	7.8	12.8	22.4	37.6	60.0
1931	9.1	19.7	32.3	46.8	67.4
1932	4.5	11.8	21.2	39.6	64.1
1933	6.2	11.7	25.6	52.4	
1934	4.6	13.6	19.3		
1935	4.2	9.6			
1936	4.2				

Table 1 shows the average failures per 100 track miles of rail in service which occurred in one to five years' service in the rail reported from rollings of 1932 to 1936, inclusive, from all mills, together with similar rates of older rollings taken from previous reports which include both Bessemer and open hearth rails. Both service and detected failures are included in this table.

The 1932 rollings, whose period of observation is now concluded, show an average rate of 64.1 failures per 100 track miles for the five-year period, which is a decrease of 0.3 compared with the rate reported last year for the 1931 rollings.

TABLE 2.—ACCUMULATED FAILURES AND FAILURE RATES FROM DATE ROLLED TO DECEMBER 31, 1937, BY MILLS, COMPUTED BY MILE YEARS OF RAIL IN SERVICE. ORIGINAL TRACK MILES ARE INCLUDED FOR INFORMATION ONLY.

YEAR ROLLED	ORIG'L TRK. MLS.	FAILURES TO DEC. 31, 1937					ORIG'L TRK. MLS	FAILURES TO DEC. 31, 1937				
		SERVICE		SERV. & DET.				SERVICE		SERV. & DET.		
		TOTAL	PER 100 TRK. MLS PER YR.	TOTAL	PER 100 TRK MLS PER YR.	PER 100 TRK. MLS.		TOTAL	PER 100 TRK MLS PER YR.	TOTAL	PER 100 TRK MLS. PER YR.	PER 100 TRK MLS.
	ALGOMA						DOMINION					
1932	46.89	34	14.65	34	14.65	73.28	—	—	—	—	—	—
1933	—	—	—	—			—	—	—	—	—	
1934	94.17	27	9.54	27	9.54		—	—	—	—	—	
1935	112.15	3	1.35	3	1.35		—	—	—	—	—	
1936	109.75	4	3.64	4	3.64		41.11	0	0.00	0	0.00	
	CARNEGIE (CARNEGIE-ILLINOIS)						ENSLEY (TENNESSEE)					
1932	189.11	87	9.81	120	13.53	67.64	270.56	131	9.98	294	22.41	112.04
1933	236.60	34	3.77	56	6.21		150.78	83	14.07	233	33.49	
1934	551.38	52	4.10	56	4.43		571.28	42	2.56	59	3.60	
1935	260.26	5	0.96	8	1.53		460.65	26	3.10	29	3.46	
1936	475.00	9	2.09	10	2.33		522.63	26	5.57	35	7.49	
	GARY (CARNEGIE-ILLINOIS)						INLAND					
1932	170.28	47	5.95	49	6.20	31.01	106.14	12	2.39	14	2.79	13.94
1933	197.19	44	5.66	164	21.11		96.36	9	2.60	13	3.76	
1934	726.65	329	16.77	346	17.63		235.71	18	2.62	18	2.62	
1935	478.03	104	10.96	120	12.64		157.64	7	2.35	7	2.35	
1936	116.12	59	6.46	59	6.46		392.51	14	3.92	14	3.92	
	LACKAWANNA (BETHLEHEM)						MARYLAND (BETHLEHEM)					
1932	158.21	136	17.39	224	28.64	143.22	99.23	31	6.35	60	12.29	61.47
1933	120.45	22	5.05	25	5.73		58.64	23	11.06	27	12.98	
1934	397.70	44	3.77	46	3.94		152.66	6	1.54	6	1.54	
1935	132.94	12	4.53	14	5.28		15.93	0	0.00	0	0.00	
1936	221.96	8	3.69	9	4.15		41.30	0	0.00	0	0.00	
	MINNEQUA (COLORADO)						STEELTON (BETHLEHEM)					
1932	233.78	17	1.47	25	2.17	10.84	66.63	3	0.37	8	2.60	12.97
1933	134.46	15	2.79	18	3.35		87.35	0	0.00	0	0.00	
1934	272.51	7	0.94	7	0.94		408.42	13	1.49	14	1.60	
1935	267.60	6	1.13	6	1.13		129.75	1	0.39	1	0.39	
1936	472.39	5	1.07	5	1.07		282.44	1	0.44	2	0.89	
	ALL MILLS (EXCL. ALGOMA & DOMINION)						ALL MILLS (INCL. ALGOMA & DOMINION)					
1932	1293.94	464	7.46	794	12.76	63.89	1340.83	498	7.72	828	12.83	64.15
1933	1081.83	230	5.62	536	13.10		1081.83	230	5.62	536	13.10	52.39
1934	3336.31	511	5.85	552	6.32		3430.48	538	5.97	579	6.43	19.28
1935	1922.80	161	4.35	185	5.00		2034.95	164	4.18	188	4.80	9.59
1936	3568.85	122	3.92	134	4.30		3719.71	126	3.86	138	4.23	4.23
TOTALS	11,203.73	1488		2201			11,607.80	1556		2269		

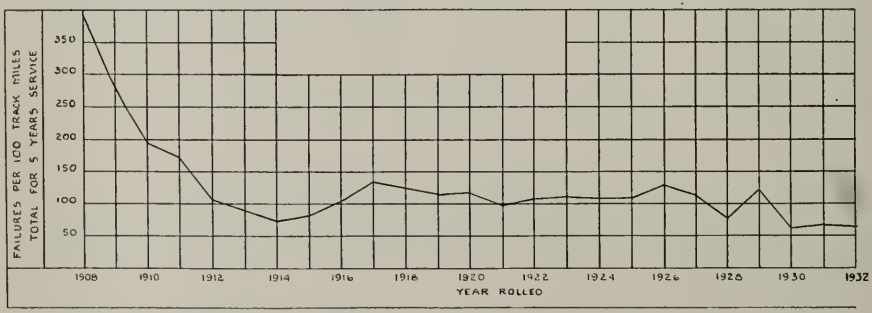


FIG. 1.—Service and Detected Rail Failures in the United States and Canada (Five Years' Service).

Fig. 1 shows diagrammatically the five-year averages from Table 1.

Table 2 presents the accumulated failures and failure rates of rail from each of the mills for each of the rollings of 1932 and succeeding years. Service and service plus detected rates are shown separately.

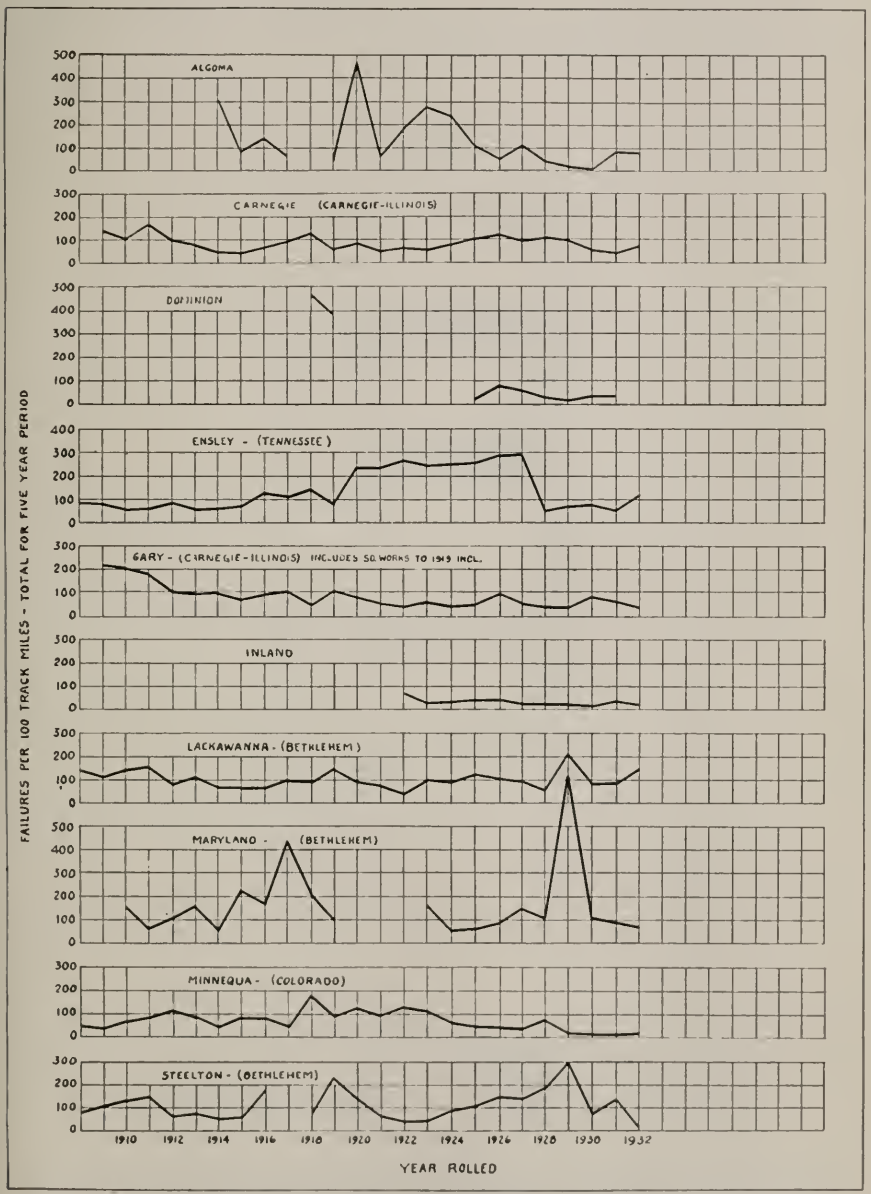

ALGOMA
CARNEGIE (CARNEGIE-ILLINOIS)
DOMINION
ENSLEY - (TENNESSEE)
GARY - (CARNEGIE-ILLINOIS) INCLUDES SO WORKS TO 1949 INCL.
INLAND
LACKAWANNA - (BETHLEHEM)
MARYLAND - (BETHLEHEM)
MINNEQUA - (COLORADO)
STEELTON - (BETHLEHEM)
FAILURES PER 100 TRACK MILES - TOTAL FOR FIVE YEAR PERIOD
1910 1912 1914 1916 1918 1920 1922 1924 1926 1928 1930 1932
YEAR ROLLED

Fig. 2.—Record of Failures per 100 Track Miles for Five Years' Service for Rollings from 1908 to 1932 (Service and Detected Failures Included).

Fig. 2 shows diagrammatically the failure rates per 100 track miles of the 1932 rollings from Table 2, for combined service and detected failures. The five-year rates for earlier rollings are reproduced from previous reports.

Fig. 3 shows diagrammatically the Table 2 failure rates per 100 track miles per year, separately for service and service plus detected failures, for each of the 1932 and subsequent rollings, by mills, unweighted for traffic.

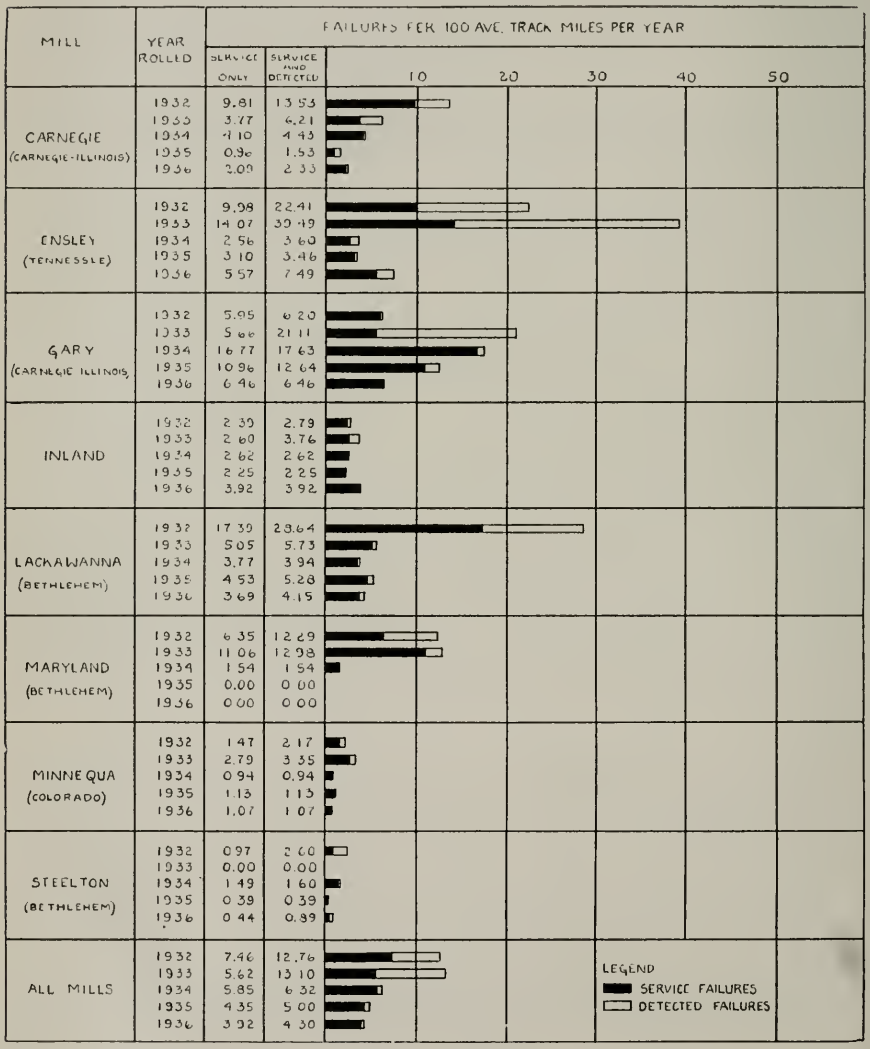


FIG. 3.—Failure Rates from Date Rolled to December 31, 1937, by Mills (Service and Detected Failure Rates Shown Separately).

Fig. 4 shows diagrammatically the comparative performance of the mills from data underlying Fig. 3, except that average traffic density factors have been introduced to the final computations using the method described on pp. 369–70 of Volume 32, AREA Proceedings for 1931. No claim is made for the entire accuracy of this method of rating, but it does give more consideration to the service to which the rails from the respective mills are subjected than does the method of rating on which Fig. 3 is based.

Table 3 shows the average weights of rail from the various mills and from all mills included in these statistics.

MILL	YEAR ROLLED	FAILURES PER 100 AVE. TRACK MILES PER YEAR PER UNIT OF TRAFFIC DENSITY: SERVICE ONLY	SERVICE AND DETECTED
CARNEGIE (CARNEGIE-ILLINOIS)	1932	2.70	3.73
	1933	0.90	1.63
	1934	1.26	1.36
	1935	0.24	0.39
	1936	0.62	0.69
ENSLEY (TENNESSEE)	1932	7.92	17.79
	1933	12.68	35.58
	1934	2.25	3.16
	1935	2.90	3.23
	1936	4.84	6.51
GARY (CARNEGIE-ILLINOIS)	1932	3.34	3.48
	1933	1.81	6.74
	1934	8.56	8.99
	1935	6.09	7.02
	1936	3.96	3.96
INLAND	1932	1.18	1.58
	1933	0.75	1.09
	1934	1.16	1.16
	1935	1.09	1.09
	1936	2.02	2.02
LACKAWANNA (BETHLEHEM)	1932	6.51	10.73
	1933	1.71	1.94
	1934	1.72	1.80
	1935	1.90	2.22
	1936	1.52	1.71
MARYLAND (BETHLEHEM)	1932	5.52	10.69
	1933	3.43	4.03
	1934	0.75	0.75
	1935	0.00	0.00
	1936	0.00	0.00
MINNEQUA (COLORADO)	1932	1.43	2.11
	1933	2.79	3.35
	1934	0.85	0.85
	1935	0.80	0.80
	1936	0.98	0.98
STEELTON (BETHLEHEM)	1932	0.38	1.03
	1933	0.00	0.00
	1934	0.68	0.73
	1935	0.13	0.13
	1936	0.16	0.35
ALL MILLS	1932	3.91	6.68
	1933	2.06	4.80
	1934	2.96	3.16
	1935	2.13	2.49
	1936	2.05	2.24

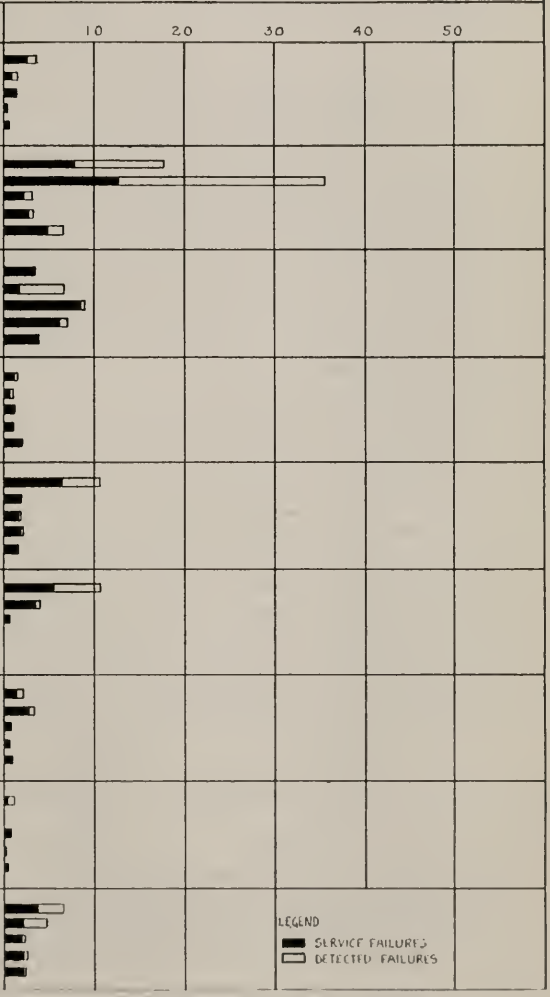


Fig. 4.—Failure Rates from Year Rolled to December 31, 1937, by Mills, Altered by Traffic Density Factors (Service and Detected Failure Rates Shown Separately).

Table 3.—Average Weights of Rails Compiled From Tonnages Used in This Report

Mill	1932	1933	1934	1935	1936
Algoma	97.7	....	105.1	106.7	105.3
Dominion	....	....	....	....	99.9
Edgar Thomson	128.1	129.6	128.9	128.8	127.1
Ensley	101.6	103.3	105.7	106.3	106.9
Gary	111.6	119.6	115.9	116.1	116.1
Inland	109.4	121.9	118.0	119.3	117.2
Lackawanna	119.3	124.0	122.3	121.3	120.9
Maryland	105.0	122.9	120.4	124.8	127.1
Minnequa	110.0	111.2	114.9	116.8	112.8
Steelton	128.4	132.7	124.8	123.6	125.1
All Mills	112.2	120.4	118.1	116.2	116.5

Appendix D

(3) TRANSVERSE FISSURE FAILURE STATISTICS

By W. C. Barnes, Engineer of Tests, Rail Committee

These statistics constitute a cumulative record of transverse fissure failures that have been reported up to and including December 31, 1937. They include all fissured rails reported, whether located by actual breakage in track or detected before breakage by inspection or test. This total, however, does not represent all such failures that have occurred for the reason that while the records of some roads have been cumulative for over 20 years, those of other roads are of more recent origin and furthermore some roads do not report such failures. Compound fissures and horizontal split heads (horizontal fissures) are not included.

Table 1 corresponds with Table 1 of last year's report and shows separately the number of service and detected transverse fissure failures classified by roads and by year failed. It includes data only from such roads as have consistently reported service failures over a long period of years and have also reported separately the service and detected failures since the introduction of detection methods in 1929. The total failures on any one road or on all roads during any given year can be obtained by adding the corresponding figures for the service failures and detected failures appearing in this table.

Table 1 differs from Table 1 of last year's report, however, in that data for the Southern Pacific (Pacific Lines) have been included for all years, Michigan Central and Northern Pacific data for 1936, and Delaware, Lackawanna & Western detected failures for 1935, 6 and 7 have been revised; and several changes in the grouping of roads under systems have been made, as fully explained in the footnotes to Table 1.

The total fissure failures reported in 1937, compared with the 1936 revised totals, are:

	Service	*Detected*	*Total*
1937	7,024 (39.1 percent)	10,955 (60.9 percent)	17,979 (100 percent)
1936	5,924 (39.3 percent)	9,126 (60.7 percent)	15,050 (100 percent)
Excess in 1937	1,100	1,829	2,929
OR	18.6 percent	20.1 percent	19.5 percent

The number of service failures in 1937, namely 7,024, is greater than has been reported in any previous year. The nearest approaches to this figure are the 5,924 reported in 1936 and 5,760 reported in 1929, in which latter year detector-car testing was introduced. The inclusion of the Southern Pacific data in Table 1 is not responsible for this increase.

Fig. 1 presents graphically the fissure failures by year failed from Table 1. The solid line shows the service failures; the broken line, the detected failures only; and the dotted line, the total service plus detected failures.

TABLE 1.—TRANSVERSE FISSURE FAILURES BY RAILROAD AND YEAR FAILED[a]

ALL	SERVICE FAILURES																DETECTED FAILURES[b]									
	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930[c]	1931	1932	1933	1934	1935	1936	1937	Total	1927	1930	1931	1932	1933	1934	1935	1936	1937	Total	Total
A. T. & S. F	40	25	177	220	134	126	81	79	71	98	126	91	142	114	84	64	46	35	46	64	1,863	0	0	0	0	13	77	121	59	306	476	2,339
A. C. L.									11	9	27	25	21	29	37	15	33	48	62	102	419	0	66	0	0	66	0	0	159	160	474	893
Balt. & Ahio									11	2	6	4	7	2	1	1	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	28
B. & M.																																
B. & O.					9	55	69	72	78	44	34	55	22	33	17	24	18	12	14	577	0	17	0	19	45	17	0	241	297	546	1,123
Can. Pac.			4	0	8	16	228	306	365	248	475	431	372	506	383	397	228	356	325	425	5,838	53	0	0	182	217	398	618	530	652	2,650	8,488
							86	158	277	174	160	108	138	106	89	88	94	110	122	137	1,954	0	0	351	214	474	834	916	999	1,502	5,284	7,238
C. of Ga.	106	52	23	41	31	29	24	40	20	20	42	92	80	42	74	56	81	54	61	55	1,026	0	80	0	107	18	136	101	96	119	657	1,683
C. R. R. of N. J.										34	28	95	73	59	40	61	85	58	110	112	785	0	55	111	0	0	0	0	0	0	166	951
C. & E. I.									4	0	22	41	18	18	28	39	23	14	18	22	247	28	0	59	0	74	43	65	29	65	363	610
C. & O.					6	39	99	131	119	210	108	195	258	181	239	330	285	316	300	227	314	3,352	22	376	667	323	978	584	1,262	1,392	911	6,515	9,867
C. & N. W.									85	63	47	62	191	86	119	81	99	69	65	41	909	16	31	110	218	110	311	155	336	317	1,614	2,523
C. M. St. P. & P.	2	0	6	5	14	11	11	13	5	9	26	11	26	45	105	125	89	99	71	74	711	43	0	49	0	136	179	247	197	357	1,228	1,939
C. R. I. & P.	10	2	11	25	37	75	75	114	98	97	90	123	111	116	131	139	136	97	135	121	1,711	20	0	18	93	13	274	63	132	344	956	2,667
D. L. & W.	474	193	0	240	169	91	60	73	113	128	86	92	139	98	64	102	82	65	49	44	1,422	0	0	0	0	0	173	214	228	474	1,189	3,523
Erie					15	43	89	100	118	148	128	235	166	175	181	179	187	171	167	229	2,331	27	2	1	0	75	0	0	0	1	106	2	427
G. N.										58	221	175	189	141	126	128	143	179	246	276	1,882	0	25	0	0	6	144	114	48	69	446	2,328
I. C.	11	35	121	190	372	556	419	501	614	658	615	597	439	0	0	0	0	0	0	0	7,610	25	126	291	217	273	169	284	314	447	1,998	9,608
I. H. B.						1	3	3	0	0	0	0	0	0	0	0	3	2	6	0	18	0	0	0	0	0	0	0	0	0	0	18
L. & H. R.				1	0	4	4	16	33	10	7	8	3	11	3	4	2	0	1	5	112	0	0	0	0	0	0	0	0	0	0	112
L. & N. E.						32	0	0	0	0	0	6	1	0	6	3	2	7	0	0	57	0	0	0	0	0	0	16	0	24	40	97
L. V.				57	89	113	92	75	75	55	60	39	22	17	34	20	31	22	28	330	0	0	0	78	0	0	0	140	0	140	0	536	1,197
L. & N.	474	9	17	33	43	77	90	75	141	295	374	456	285	268	220	182	215	181	253	229	3,917	101	165	0	0	358	19	341	488	577	2,049	5,966
M. K. T.				2	11	15	17	29	18	26	35	33	30	31	32	30	17	20	33	39	426	10	12	29	76	31	98	74	77	167	574	1,000
M. & O.									30	59	18	26	32	42	24	25	26	16	75	30	423	4	0	0	0	0	0	1	0	0	5	429
N. C. & St. L.	10	0	1	2	2	8	5	7	3	16	15	34	22	59	42	58	20	19	50	36	398	0	2	0	0	0	40	45	17	42	146	545
N. Y. C. System	419	101	112	141	200	141	173	294	319	384	381	444	340	306	295	306	272	318	381	361	5,642	27	197	83	182	253	134	191	322	322	1,601	7,243
N. Y. N. H. & H.				12	28	26	57	63	34	27	51	40	28	24	40	59	34	37	48	606	17	67	159	106	101	100	82	60	101	793	1,399
N. Y. O. & W.																																
N. & W.					3	17	45	29	18	16	18	23	43	41	23	50	33	23	38	36	464	0	20	0	5	0	74	0	0	94	183	547
N. P.					42	30	120	161	152	184	166	186	131	171	160	126	169	168	171	259	2,379	48	0	0	0	0	81	19	324	173	292	937	3,316
P. R. R.	2,244	1,114	1,129	1,106	912	606	512	787	871	747	574	584	572	426	317	344	439	450	508	586	14,888	0	192	378	378	818	429	1,043	700	751	1,689	19,577
Reading					52	112	107	91	36	42	39	53	57	109	111	124	160	166	162	166	1,585	0	0	0	0	0	0	0	0	0	0	1,585
R. F. & P.							0	0	0	0	1	0	1	3	5	4	2	4	2	4	21	3	0	0	0	36	0	67	44	33	203	227
Rutland								3	2		2		3	1	0	1	0	1	1	1	16	0	0	0	7	0	0	3	0	0	10	26
Soo, System						24	6	13	51	123	191	208	201	183	160	167	232	261	358	504	2,709	0	0	0	0	0	0	0	0	0	0	2,709
S. P. Pac. Lines		57	9	6	130	118	143	175	243	325	397	536	560	458	331	322	269	208	206	324	481	5,236	0	131	251	142	374	580	455	767	629	3,329	8,565
U. P.				36	262	557	499	480	368	326	380	438	497	495	535	517	936	1,003	1,176	1,443	9,947	34	0	0	187	187	321	660	1,361	1,437	1,998	6,103	16,050
Virginian										10	12	7	24	24	28	33	39	53	36	227	0	0	0	0	0	0	0	0	0	0	0	227
Wab. Md.							65	111	164	212	57	255	148	91	94	62	87	116	70	1,535	0	0	0	0	0	106	0	0	86	192	1,727
All Roads	3,847	1,544	1,843	2,116	2,472	3,277	3,257	4,139	4,620	4,993	5,458	5,760	5,257	4,795	4,624	4,463	4,994	5,067	5,924	7,024	85,478	478	1,464	2,686	2,430	4,895	5,614	8,169	9,126	10,955	45,806	131,279

Notes—

a Roads not reporting service and detected failures separately are not included.
b Detection methods first used to any extent in 1929.
c 1930 data cover 11 months only, because of change in fiscal year.
d B. R. & P. included with B. & O.
e N. V. included with C. & O. Pere Marquette 1937 failures included with C. & O.
f B. & A., C. C. C. & St. L., Mich. C., N. Y. C. (E), & N. Y. C. (W) now grouped under N. Y. C. system. Mich C. failures in last half of 1936, not previously reported, are included.
g 1936 data revised account supplementary report received from road.
h Long Island R. R included with P. R. R.
i S. P. Pac. Lines for all years added.
k L. A. & S. L. included with U. P.
l 1935, & & 7 detected failures revised because of supplementary report from road.

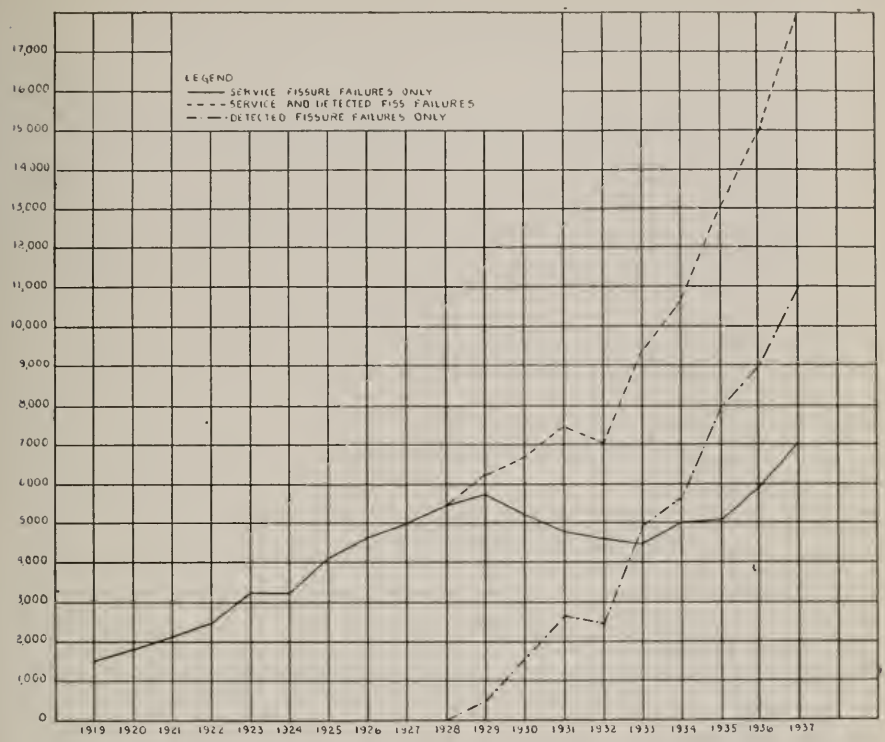


FIG. 1.—Fissure Failures Reported Each Year (1930 Includes 11 Months Only).

Table 2 shows all transverse fissure failures, service plus detected, reported by all roads for each year's rollings from each mill accumulated from the year rolled to December 31, 1937. These data are unweighted for tonnage output of mills, for density of traffic or for years of service. Reports from all roads are included and hence the grand total of accumulated transverse fissure failures (131,555) exceeds that shown in Table 1. This table is most useful in comparing the failures in the various years' rollings from any one mill. Fissure failures reported since 1924, as occurring in the first year of service, are as follows:

29	Failures	in	1925	from	1925	Rollings,	All	Mills
50	"	"	1926	"	1926	"	"	"
114	"	"	1927	"	1927	"	"	"
58	"	"	1928	"	1928	"	"	"
106	"	"	1929	"	1929	"	"	"
33	"	"	1930	"	1930	"	"	"
32	"	"	1931	"	1931	"	"	"
3	"	"	1932	"	1932	"	"	"
0	"	"	1933	"	1933	"	"	"
0	"	"	1934	"	1934	"	"	"
3	"	"	1935	"	1935	"	"	"
3	"	"	1936	"	1936	"	"	"
1	"	"	1937	"	1937	"	"	"

TABLE 2.—ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1937 BY YEAR ROLLED AND BY MILL

(Includes Fissured Rails Detected Before Actual Failure in Track)

Year Rolled	UNKNOWN			ALGOMA			SAUCON (Bethlehem)			CAMBRIA			CARNEGIE (Carnegie-Illinois)			COLORADO		
	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total
Unknown	154	22	176	13	1	14	54	2	56	50	2	52	64	9	73	36	0	36
Prior	19	11	30	46	6	52	1,967	10	1,977	510	1	511	375	15	390	11	0	11
1910	19	1	20	15	2	17	910	28	938	125	1	126	41	8	49	467	11	478
1911	7	1	8	16	1	17	1,048	5	1,053	367	0	367	63	1	64	664	49	709
1912	14	4	18	9	3	12	179	8	187	799	33	832	85	8	93	130	21	151
1913	33	9	42	9	4	13	356	11	367	692	15	707	105	17	122	84	16	100
1914	8	2	10	49	1	50	160	1	161	396	17	413	47	4	51	137	8	145
1915	3	8	11	639	38	677	174	12	386	140	3	143	59	5	64	252	8	260
1916	4	8	12	150	12	162	400	19	419	117	2	119	108	3	111	590	27	617
1917	4	1	5	8	1	9	280	5	285	176	3	179	90	17	107	978	129	1,107
1918	2	0	2	439	16	455	112	2	114	106	9	115	89	6	95	221	38	259
1919	4	4	8	604	51	655	320	0	320	21	2	23	28	2	30	135	22	157
1920	1	3	4	150	24	174	87	9	96	73	10	83	110	8	118	888	153	1,041
1921	4	14	18	172	33	205	209	2	211	207	10	217	151	10	161	432	112	544
1922	1	0	1	680	141	821	149	3	152	88	1	89	235	15	250	112	22	134
1923	96	0	96	712	156	868	-------	-------	-------	69	2	71	237	22	259	94	8	102
1924	66	0	66	1,044	268	1,312	-------	-------	-------	-------	-------	-------	242	19	261	87	21	108
1925	57	0	57	142	62	204	-------	-------	-------	-------	-------	-------	334	24	358	127	44	171
1926	22	1	23	71	53	124	-------	-------	-------	-------	-------	-------	681	88	769	134	85	219
1927	28	2	30	257	164	421	-------	-------	-------	-------	-------	-------	592	73	665	147	64	211
1928	1	1	2	340	261	601	-------	-------	-------	-------	-------	-------	680	138	818	138	129	267
1929	0	0	0	42	12	54	-------	-------	-------	-------	-------	-------	488	120	608	42	54	96
1930	1	0	1	2	1	3	-------	-------	-------	-------	-------	-------	194	49	243	14	16	30
1931	-------	0	0	10	8	18	-------	-------	-------	-------	-------	-------	82	33	115	2	5	7
1932	-------	0	0	11	17	28	-------	-------	-------	-------	-------	-------	21	15	36	0	5	5
1933	-------	1	1	0	0	0	-------	-------	-------	-------	-------	-------	6	17	23	0	0	0
1934	-------	-------	-------	11	13	24	-------	-------	-------	-------	-------	-------	1	5	6	0	0	0
1935	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	1	1	2	2	4
1936	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	0	0
1937	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	1	1
Totals	548	93	641	5,641	1,349	6,990	6,605	117	6,722	3,936	111	4,047	5,208	732	5,940	5,924	1,046	6,970

TABLE 2.—ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1937 BY YEAR ROLLED AND BY MILL—Continued

(Includes Fissured Rails Detected Before Actual Failure in Track)

Year Rolled	DOMINION			GERMAN			GARY* (Carnegie-Illinois)			INLAND			LACKAWANNA (Bethlehem)**		
	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total
Unknown	3	1	4				195	16	211	16	1	17	39	3	42
Prior	187	23	210				1,327	179	1,506				387	33	420
1910	1	0	1				3,124	182	3,306				358	38	396
1911	0	0	0				353	25	378				424	7	431
1912	77	5	82				2,038	151	2,189				1,098	38	1,136
1913	6	3	9				2,069	137	2,206				1,188	68	1,256
1914	22	5	27				639	57	696				885	31	916
1915	0	0	0				889	96	985				601	45	646
1916	2	0	2				1,568	180	1,748				196	27	223
1917	0	0	0				4,240	437	4,677				205	16	221
1918	130	8	138				1,458	237	1,695				172	13	185
1919	82	7	89				2,734	500	3,234				149	16	165
1920	1	0	1				1,438	171	1,609				263	10	273
1921	2	0	2				1,706	509	2,215				265	17	282
1922	0	0	0				704	227	931	301	24	325	285	15	300
1923	0	0	0				2,110	577	2,687	240	31	271	762	50	812
1924	0	0	0				1,512	530	2,042	593	151	744	345	45	390
1925	327	129	456				1,133	430	1,563	355	142	497	631	74	705
1926	143	164	307	9	2	11	1,876	518	2,394	595	185	780	1,056	175	1,231
1927	11	3	14				1,248	421	1,669	197	65	262	1,044	188	1,232
1928	4	6	10				342	126	468	202	70	272	492	66	558
1929	3	5	8				237	122	359	85	47	132	667	194	861
1930		4	4				1,023	373	1,396	31	16	47	32	9	41
1931							392	225	617	59	84	143	23	20	43
1932							7	6	13	0	2	2	2	1	3
1933							58	59	117	2	2	4	1	0	1
1934							1	10	11				1	2	3
1935							5	20	25				1	1	2
1936							3	3	6					1	1
1937															
Totals	1,001	363	1,364	9	2	11	34,429	6,524	40,953	2,676	820	3,496	11,572	1,203	12,775

* Includes South Works prior to 1920.

**Prior to 1903 was Scranton mill of Lackawanna Iron & Steel Co.

TABLE 2.—ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1937 BY YEAR ROLLED AND BY MILL—Continued

(Includes Fissured Rails Detected Before Actual Failure in Track)

Year Rolled	LORAIN (Carnegie-Illinois)			MARYLAND (Bethlehem)			STEELTON (Bethlehem)			ENSLEY (Tennessee)			ALL MILLS		
	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total	Prior	1937	Total
Unknown	0	0	0	18	0	18	25	3	28	245	24	269	912	86	998
Prior	14	0	14	412	2	414	206	7	213	713	9	722	6,174	294	6,468
1910	0	0	0	135	2	137	139	5	144	177	4	181	5,511	282	5,793
1911	0	0	0	277	14	291	160	5	165	207	7	214	3,586	111	3,697
1912	0	0	0	216	4	220	179	22	201	173	13	186	4,997	310	5,307
1913	1	0	1	546	7	553	207	15	222	174	8	182	5,470	310	5,780
1914				157	1	158	138	8	146	257	5	262	2,895	140	3,035
1915				679	22	701	168	3	171	109	8	117	3,913	248	4,161
1916				678	28	706	52	4	56	320	18	338	4,185	328	4,513
1917				1,004	35	1,039	15	2	17	363	28	391	7,363	674	8,037
1918				146	6	152	18	1	19	571	43	614	3,464	379	3,843
1919				125	27	152	152	9	161	963	98	1,061	5,317	738	6,055
1920				4	0	4	228	9	237	309	34	343	3,552	431	3,983
1921				5	0	5	413	28	441	519	65	584	4,085	800	4,885
1922				7	0	7	147	13	160	931	119	1,050	3,640	580	4,220
1923				10	0	10	235	27	262	775	132	907	5,340	1,005	6,345
1924				45	15	60	558	49	607	1,613	271	1,884	6,105	1,369	7,474
1925				336	32	368	498	68	566	2,026	300	2,326	5,966	1,305	7,271
1926				396	43	439	762	103	865	1,956	313	2,269	7,701	1,730	9,431
1927				1,016	109	1,125	931	216	1,147	1,284	236	1,520	6,755	1,541	8,296
1928				852	130	982	1,196	315	1,511	298	75	373	4,545	1,317	5,862
1929				4,537	850	5,387	1,013	312	1,325	565	164	729	7,679	1,880	9,559
1930				487	227	714	590	103	693	192	88	280	2,566	886	3,452
1931				242	91	333	418	98	516	249	186	435	1,477	750	2,227
1932				24	51	75	8	5	13	126	116	242	199	218	417
1933				6	11	17		0	0	73	101	174	146	191	337
1934					0	0		1	1	0	5	5	14	36	50
1935					0	0		0	0	8	8	16	16	32	48
1936					1	1		1	1		1	1	3	7	10
1937														1	1
Totals	15	0	15	12,360	1,708	14,068	8,456	1,432	9,888	15,196	2,479	17,675	113,576	17,979	131,555

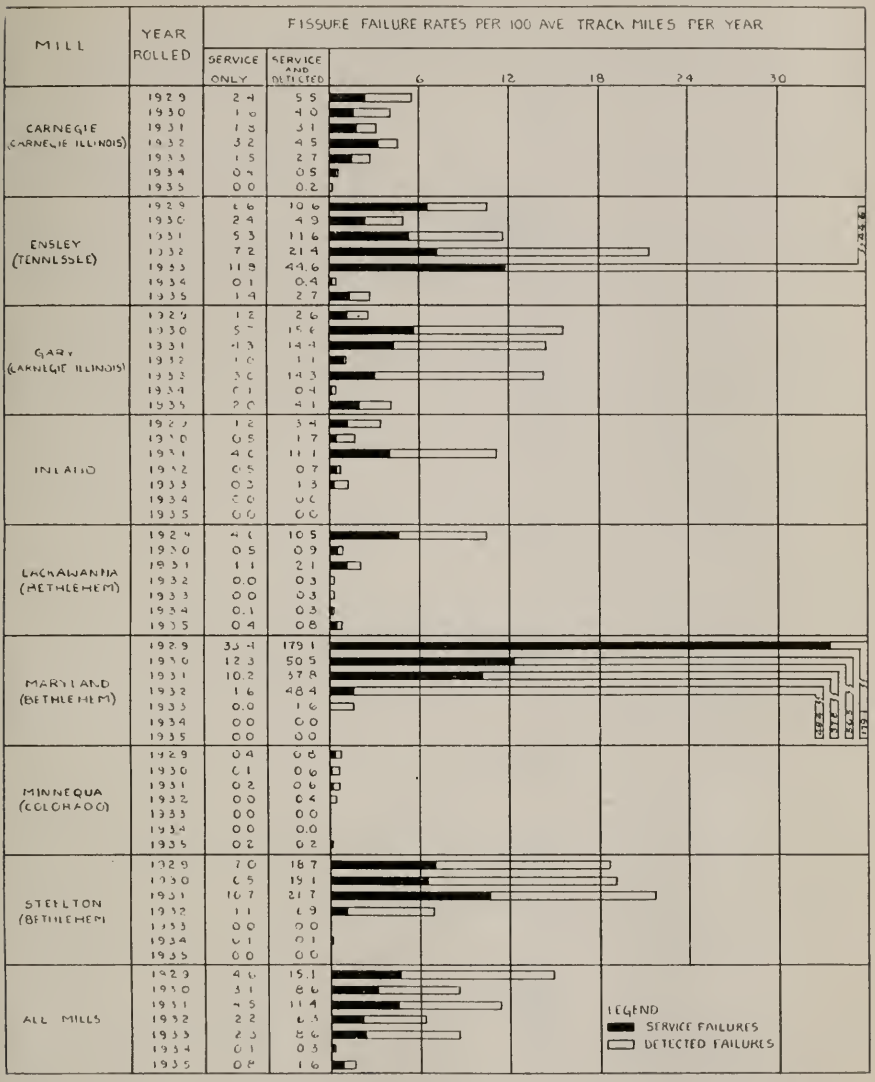


FIG. 2.—Fissure Failure Rates from Date Rolled to December 31, 1937, by Mills (Service and Detected Failure Rates Shown Separately).

Fig. 2 is a mill rating chart and shows separately the service and detected transverse fissure failure rates per 100 average track miles per year of each of the 1929 to 1935 rollings, inclusive, of each mill from the date rolled to December 31, 1937, unweighted for traffic. It will be noted that the number of rollings included in this chart is greater than has been included in former reports.

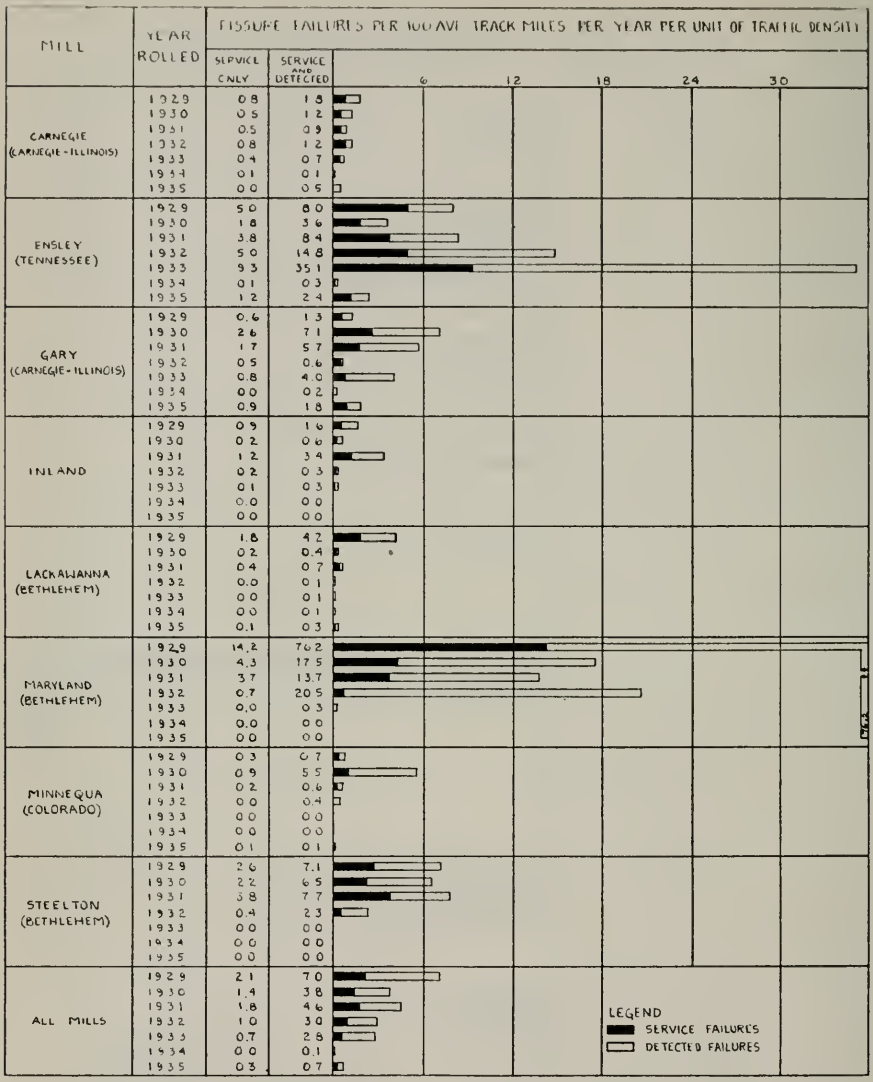


FIG. 3.—Fissure Failure Rates from Date Rolled to December 31, 1937, by Mills, Altered by Traffic Density Factors (Service and Detected Failure Rates Shown Separately).

Fig. 3 shows graphically the average rates of failure, by mills, from Fig. 2, modified by the application of average traffic density factors, the derivation of which is explained on pages 369–70 of Volume 32 of the AREA Proceedings for 1931. Owing to the necessity of using factors obtained from average traffic per mile of road, instead of actual traffic over the particular rails in question, this chart can be considered only as an approximation.

Appendix E

(3) CONTROLLED COOLED AND BRUNORIZED RAIL

By W. C. Barnes, Engineer of Tests, Rail Committee

Data is being accumulated to assist in determining the performance of controlled cooled and Brunorized rail in service.

From Table 1, which gives the tonnages of all such contract rail, from all mills, laid in track of roads represented on the Rail committee, as reported to June 30, 1938, it will be seen that the total tonnage laid as of that date was 1,096,018.

The various mills did not all start producing these special rails in the same year; the rollings included therefore vary as between mills. The latest contract rollings included are those of 1937 and the earliest are as follows: Dominion—1931, Algoma—1933, Carnegie and Inland—1935, and Colorado, Gary, Lackawanna, Steelton and Ensley—1936. The rollings of contract Brunorized rail at Gary started in 1936.

Reports received show that in all the above tonnage of controlled cooled and Brunorized rail, no failure due to transverse fissures had occurred up to December 1, 1938.

TABLE 1.—TONNAGES OF CONTRACT RAIL IN TRACK

As of June 30, 1938

CONTROLLED COOLED AND BRUNORIZED RAIL

Roads	*CC*	*Br*	*Total CC & Br*	*Remarks*
A. T. & S. F.	120,336	3,571	123,907	
B. & O.	5,000		5,000	
B. & M.	6,223		6,223	
C. P.	118,711		118,711	
C. N.	97,393		97,393	
C. & N. W.	35,154	4,456	39,610	
C. & O.	90,601		90,601	
C. B. & Q.	46,976	5,783	52,759	
C. M. St. P. & P.	21,336	9,017	30,353	
C. R. I. & P.				No report received
D. & H.	9,900		9,900	
D. & R. G. W.	14,226		14,226	
D. L. & W.	27,270		27,270	
Erie	47,033		47,033	
G. N.	14,812	5,761	20,573	
I. C.	18,921	4,481	23,402	
K. C. S.	5,718	2,408	8,126	
L. & N.	26,270		26,270	
Me. Cent.	3,165		3,165	
M. K. T.				No tonnage
M. P.	10,973		10,973	
N. Y. C.	49,993	11,823	61,816	
N. Y. C. & St. L.	26,414		26,414	
N. Y. N. H. & H.	8,959		8,959	
N. & W.	14,175		14,175	
N. P.	16,143		16,143	
P. R. R.	43,978		43,978	
P. M.	15,356		15,356	
Reading				No tonnage
S. P. (Pacific Lines)	112,172		112,172	
Sou. Sys.	41,510		41,510	
U. P.				No report received
Total	1,048,718	47,300	1,096,018	

(3) THE AAR DETECTOR CAR

By W. C. Barnes, Engineer of Tests, Rail Committee

The AAR leasing service with the Sperry type car, operated under the direction of the engineer of tests, is now in its tenth year, and satisfaction with its efficiency and low cost is evidenced on the part of lessee roads by their repeated requests for service in successive years.

Appendix F

(4) CAUSE AND PREVENTION OF RAIL BATTERING AND METHODS OF RECONDITIONING RAIL ENDS, FASTENINGS, AND FROGS IN TRACK

F. M. Graham, Chairman, Subcommittee; M. M. Backus, W. C. Barnes, H. A. Cassil, E. E. Chapman, H. R. Clarke, Robert H. Ford, B. Herman, W. H. Kirkbride, G. M. Magee, Ray McBrian, Wm. Michel, C. E. Morgan, John V. Neubert, J. C. Patterson, J. C. Ryan, G. R. Smiley, C. P. Van Gundy, J. C. Wallace, Louis Yager.

Subcommittee 4 of the Rail committee, has continued to receive the assistance of the Rails Investigation of the University of Illinois in making laboratory studies of submitted samples of rail end hardening as done by various methods, both at rail mills and in the track. The results of these studies are shown in the quarterly reports of the Rails Investigation.

While the laboratory work is very helpful in studying this subject, it is believed that final conclusions can only be obtained from field tests. Because of the very limited rail programs on available railroads during the past year, it has not been found possible to initiate field tests where new rail was being laid in locations where desired alinement, grades, speed and heavy traffic were available.

Such tests have been fully outlined and arrangements made whereby the field observations and measurements will be undertaken by the Rails Investigation.

Some progress has been made in the study of reconditioning of rail ends by welding, but it seems desirable to develop the proper method of hardening new rail ends before undertaking the hardening of built-up rail ends.

This is submitted as a progress report, with the recommendation that the subject be continued.

Appendix G

(5) ECONOMIC VALUE OF DIFFERENT SIZES OF RAIL

J. M. Farrin, Chairman, Subcommittee; W. C. Barnes, N. J. Boughton, W. J. Burton, W. A. Duff, F. W. Gardiner, C. W. Johns, G. M. Magee, John V. Neubert, A. N. Reece, Barton Wheelwright, Louis Yager.

Further studies have been made of this subject, but the committee feels it is not ready to make a report on it. It is recommended that this be received as a progress report and that the subject be continued.

Appendix H

(6) ECONOMICS OF RAIL LENGTHS IN EXCESS OF 39 FEET

A. N. Reece, Chairman, Subcommittee; J. B. Akers, W. C. Barnes, A. F. Blaess, W. J. Burton, J. M. Farrin, R. H. Ford, G. W. Harris, C. W. Johns, John V. Neubert, J. C. Patterson, W. H. Penfield, G. A. Phillips, B. H. Prater, R. T. Scholes, J. C. Wallace, J. E. Willoughby, W. P. Wiltsee, Louis Yager.

The comparative economic benefits of three rail lengths have been analyzed in detail in the tabulation marked Exhibit A. This analysis includes 112-lb. and 131-lb. rail sections, with an assumed life of 20 years for either section, dependent upon traffic density and physical conditions where the rail is laid.

The assumed joint repair cost is based on two conditions: (1) with rail not end-hardened it is assumed the ends would be built up twice by welding during the 20-year period; (2) with end-hardened rail it is assumed two cross-grindings and one surface-grinding would be sufficient. This is based on the actual experience of one railroad which has had ten years' experience with end-hardened rail in high speed, heavy traffic territory. The assumed joint repair cost contemplates one application of reformed bars under either condition of rail ends.

The estimated savings by reduced number of joints with 45 and 78-ft. rail, compared with 39-ft. length, are summarized below:

(1) Rail not End Hardened	*Per Gross Ton of Rail*			
Building up Rail Ends Twice, Apply Reformed Bars Once	112-lb.		131-lb.	
	45-ft.	78-ft.	45-ft.	78-ft.
Elimination of joint bars	$ .45	$1.69	$ .43	$1.63
Joint repair cost	.53	1.96	.46	1.76
Joint maintenance expense	.94	3.58	.80	3.07
Rail renewal cost	.03	.23	.03	.19
Total Benefits	$1.95	$7.46	$1.72	$6.65
Less increased cost of rail failures	.10	.64	.10	.64
Net Benefits	$1.85	$6.82	$1.62	$6.01
(2) Rail End Hardened				
Grinding Rail Ends Twice, Apply Reformed Bars Once				
Elimination of joint bars	$ .45	$1.69	$ .43	$1.63
Joint repair cost	.23	.91	.23	.88
Joint maintenance cost	.94	3.58	.80	3.07
Rail renewal cost	.03	.23	.03	.19
Total Benefits	$1.65	$6.41	$1.49	$5.77
Less increased cost of rail failures	.10	.64	.10	.64
Net Benefits	$1.55	$5.77	$1.39	$5.13

In automatic signal territory, the net benefits shown above should be increased by the following amounts representing the saving per gross ton of rail in cost of bonding joints:

	112-lb.		131-lb.	
	45-ft.	78-ft.	45-ft.	78-ft.
Saving over 39-ft. rail	$ .06	$ .23	$ .05	$ .19

Exhibit "A"

Comparative Economic Benefits of Rail in 39-ft. Length Compared to 45-ft. and 78-ft. Lengths

	112 Lb. Rail			131 Lb. Rail		
	39-ft.	45-ft.	78-ft.	39-ft.	45-ft.	78-ft.
Net First Cost of Joints						
Estimated first cost of joint:	112-lb. Rail		131-lb. Rail			
113-lb. @ 3¼c per lb.	$3.67		130-lb. @ 3¼c lb.	$4.23		
6 bolts (12.75-lb. @ 4c)	.51		6 bolts (13.02-lb.)	.52		
6 spring washers @ 4c	.24		6 spring washers	.24		
	$4.42			$4.99		
Less salvage—50 percent of first cost	$ 4.42 2.21	$ 4.42 2.21	$ 4.42 2.21	$ 4.99 2.50	$ 4.99 2.50	$ 4.99 2.50
Net first cost of joint	$ 2.21	$ 2.21	$ 2.21	$ 2.49	$ 2.49	$ 2.49
Number of joints per mile	271	235	135.5	271	235	135.5
Net first cost of joints per mile	$ 598.00	$ 518.00	$ 299.00	$ 673.00	$ 585.00	$ 337.00
Net first cost of joints per gross ton of rail (176.5 GT) (206.2 GT)	3.39	2.94	1.70	3.26	2.84	1.63
Saving over 39-ft. rail in net first cost per gross ton of rail	0	.45	1.69	0	.43	1.63
Joint Repair Cost (Welding Rail Ends—Rail not end-hardened)						
Assumed life of rail—20 years						
Assumed joint repair—2 weldings and 1 application of reformed bars during this period						
Labor to remove old bars and apply reformed bars—per joint	$ .15	$ .15	$ .15	$ .15	$ .15	$ .15
Reforming cost $0.008 per lb. (113-lb. for 112-lb. rail) (130 lb. for 131-lb. rail)—per joint	.90	.90	.90	1.04	1.04	1.04
Welding rail ends twice—per joint	1.50	1.50	1.50	1.50	1.50	1.50
Total joint repair cost—per joint	$ 2.55	$ 2.55	$ 2.55	$ 2.69	$ 2.69	$ 2.69
Number of joints per mile	271	235	135.5	271	235	135.5
Total joint repair cost per mile	$ 692.00	$ 599.00	$ 346.00	$ 728.00	$ 633.00	$ 365.00
Total joint repair cost per gross ton of rail (176.5 GT for 112-lb. and 206.2 for 131-lb.)	3.92	3.39	1.96	3.53	3.07	1.77
Average cost per year—20-year life	.196	.1695	.098	.1765	.1535	.0885
Capitalized joint repair cost at 5 per cent—per gross ton of rail	3.92	3.39	1.96	3.53	3.07	1.77
Saving over 39-ft. rail in joint repair cost—per gross ton of rail	0	.53	1.96	0	.46	1.76
Joint Repair Cost (Grinding Rail Ends—End-hardened rail)						
Assumed life of rail—20 years						
Assumed joint repair—2 cross grindings and 1 application of reformed bars						
Cross grinding rail ends 2 times—cost per joint	$ .04	$ .04	$ .04	$ .04	$ .04	$ .04
Surface grinding once—cost per joint	.10	.10	.10	.10	.10	.10
Labor to remove old bars and apply reformed bars—per joint	.15	.15	.15	.15	.15	.15
Reforming cost @ $0.008 per lb.-per Joint	.90	.90	.90	1.04	1.04	1.04
Total joint repair cost per joint	$ 1.19	$ 1.19	$ 1.19	$ 1.33	$ 1.33	$ 1.33
Number of joints per mile	271	235	135.5	271	235	135.5
Total joint repair cost per mile	$ 322.00	$ 280.00	$ 161.00	$ 360.00	$ 313.00	$ 180.00
Total joint repair cost per gross ton of rail	1.82	1.59	.91	1.75	1.52	.87
Average cost per year—20-year life	.091	.0795	.0455	.0875	.076	.0435
Capitalized joint repair cost at 5 per cent—per gross ton of rail	1.82	1.59	.91	1.75	1.52	.87
Saving over 39-ft. rail in joint repair cost—per gross ton of rail	0	.23	.91	0	.23	.88

Joint Maintenance Cost							
Tightening bolts once per year:							
6 bolts at $0.01 per man-hour at $0.40	$0.024						
Oiling joints	.01						
Spotting joints once per yr. ½ man-hr. at $0.40	.20						
Estimated annual joint maintenance cost—per joint	$0.234	$ .234	$ .234	$ .234	$ .234	$ .234	$ .234
Estimated annual joint maintenance cost—per mile		63.30	55.00	31.70	63.30	55.00	31.70
Estimated annual joint maintenance cost—per gross ton of rail		.358	.311	.179	.307	.267	.1535
Estimated annual joint maintenance cost—per gross ton of rail capitalized at 5 per cent		7.16	6.22	3.58	6.14	5.34	3.07
Saving over 39-ft. rail in joint maintenance cost—per gross ton of rail		0	.94	3.58	0	.80	3.07
Rail Failure Replacement Cost							
Assume 1 rail failure in 5 miles of track per year and that rail costing $45. per GT is scrapped at $15. leaving $30. per G T net cost of replacement							
Weight of one rail—in gross tons		0.652	0.752	1.303	0.762	0.878	1.524
Material cost for replacement of 1 rail at $30 per gross ton		$ 19.56	$ 22.56	$ 39.09	$ 22.86	$ 26.34	$ 45.72
Estimated labor replacement cost		8.55	9.85	17.10	10.00	11.54	20.00
Total replacement cost per rail		$ 28.11	$ 32.41	$ 56.19	$ 32.86	$ 37.88	$ 65.72
Average replacement cost per gross ton per year		.032	.037	.064	.032	.037	.064
Average replacement cost capitalized at 5 per cent		.64	.74	1.28	.64	.74	1.28
Increased cost over 39-ft. rail for replacement of rail failures		0	.10	.64	0	.10	.64
Rail Renewal Cost							
Saving in unloading and laying cost per mile compared to 39-ft. rail		----------	$ 6.00	$ 40.00	----------	$ 6.00	$ 40.00
Saving per gross ton of rail		----------	.03	.23	----------	.03	.19
Summary of Savings per Gross Ton of Rail							
On bssis of 2 weldings and 1 application of reformed bars (Rail not end-hardened)							
Saving in net first cost of joint bars		----------	$ .45	$ 1.69	----------	$ .43	$ 1.63
Capitalized saving in joint repair cost		----------	.53	1.96	----------	.46	1.76
Capitalized saving in joint maintenance expense		----------	.94	3.58	----------	.80	3.07
Saving in rail renewal cost		----------	.03	.23	----------	.03	.19
Total Benefits		----------	$ 1.95	$ 7.46	----------	$ 1.72	$ 6.65
Less capitalized increased cost of rail failures		----------	.10	.64	----------	.10	.64
Net Benefits		----------	$ 1.85	$ 6.82	----------	$ 1.62	$ 6.01
On basis of grinding rail ends twice and 1 application of reformed bars (end-hardened rail)							
Saving in net first cost of joint bars		----------	$ .45	$ 1.69	----------	$ .43	$ 1.63
Capitalized saving in joint repair cost		----------	.23	.91	----------	.23	.88
Capitalized saving in joint maintenance expense		----------	.94	3.58	----------	.80	3.07
Saving in rail renewal cost		----------	.03	.23	----------	.03	.19
Total Benefits		----------	$ 1.65	$ 6.41	----------	$ 1.49	$ 5.77
Less capitalized increased cost of rail failures		----------	.10	.64	----------	.10	.64
Net Benefits		----------	$ 1.55	$ 5.77	----------	$ 1.39	$ 5.13

Exhibit "A"—Continued

COMPARATIVE ECONOMIC BENEFITS OF RAIL IN 39-FT. LENGTH COMPARED TO 45-FT. AND 78-FT. LENGTHS

	112 LB. RAIL			131 LB. RAIL		
	39-ft.	45-ft.	78-ft.	39-ft.	45-ft.	78-ft.
NET COST OF BONDING (Where required)						
Material—per joint $0.20						
Labor—per joint .10	$ .30	$ .30	$ .30	$ .30	$ .30	$ .30
Net first cost per mile	81.30	70.50	40.65	81.30	70.50	40.65
Net first cost per gross ton of rail	.46	.40	.23	.39	.34	.20
Saving over 39-ft. rail in net first cost per gross ton		.06	.23		.05	.19

Note: Saving in cost of bonding joints should be added to Net Benefits shown above, where bonding is required.

It is assumed that 131-lb. rail will be used in track with heavier traffic density than over 112-lb. rail and the same life of rail in years (20 years) is used for both rail sections.

In handling this assignment, the subcommittee issued a circular letter, with a tabulation similar to Exhibit A, to the chief engineers or engineers maintenance of way, of 64 Class I steam railroads or systems in the United States and 2 Canadian systems, with a route mileage aggregating approximately 224,200 miles and 40,600 miles, respectively, or a total of 66 railroads or systems with a total of approximately 264,800 miles.

A request was made for economic studies on rail lengths over 39 ft. and a recommendation for increased length, based on either the tabulation enclosed with the circular letter or on studies made by individual lines. Three lines presented data on the economic value of rail longer than 39 ft. Below is given a summary of the sentiment developed with respect to preference for rail lengths:

Rail Length Favored	*Number of Replies*	*Route Mileage*	*Percent of Mileage Canvassed*
39 ft.	7	17,336	6.5
45 ft.	8	36,757	13.9
50 ft.	2	19,700	7.4
78 ft. or longer	17	65,438	24.7
No recommendation	18	60,233	22.7
Total	52	199,454	75.3

The following is a summary of the principal points advanced by lines expressing preference for lengths under 78 ft. or making no recommendation:

1. Car supply for transporting long rails.
2. Price factor.
3. Ability of section gangs to make emergency replacements.
4. Increased expense of unloading and laying.
5. Inadequate capacity of rail-laying equipment to handle.
6. Developments in continuous welding of rails.

Following are abstracts of replies favoring 78-ft. rail length:

Road A. Practical experience with installations of 66-ft. rail has fully justified expectations as to the economies to be obtained in reduced maintenance costs. Recommend adoption of 78-ft. rail if obtainable at favorable price.

Road B. Based on test installations of 66-ft. rail, favor 78-ft. rail, price and other factors of purchase being equal to 39-ft. Anticipate no difficulty in use of 78-ft. rail with present standard track construction.

Road C. Favor 78-ft., or length as long as can be rolled at a price making its use economical.

Road D. From experience with continuous welded rail it is believed that the longest rail that could be rolled would be advantageous and result in much economy to lines adopting continuous welded rail, due to reduction in number of joints to be welded.

Road E. Aside from price factor and savings which can be evaluated, there are intangible benefits not susceptible of monetary evaluation which far outweigh in reality the benefits that can be reduced to monetary terms.

Road F. Recommend 78-ft. rail if obtainable at favorable price. Estimate saving per ton of 112-lb. rail of $3.40 and $12.84 for 45-ft. and 78-ft. lengths, respectively, and for 131-lb. rail $3.09 and $11.70 for 45-ft. and 78-ft. lengths. In welding rails of these lengths there would be additional savings ranging from $3.09 to $5.17 per ton, varying with length and weight of rail and whether Thermit or flash-weld.

The absence of definite information on the base price of rail longer than 39 ft. seems to be a controlling factor in causing many roads to refrain from definite commitment on the adoption of a longer rail. If it were definitely known that a longer standard rail could be obtained at a favorable price, it is believed a majority of the roads would favor its adoption as standard.

The question of cars for shipment of 78-ft. rail does not appear to be an important factor, since one double load of 78-ft. rail would be equivalent in weight of two single loads of 39-ft. rail and there would be no penalty due to minimum weight requirements.

Some concern is expressed regarding additional expense of unloading and laying 78-ft. rail. However, it has been the practical experience of roads which have laid 66-ft. and 78-ft. rail that planning will permit the unloading and laying of rail longer than 39 ft. with practically no increased expense in these items.

The objection is made that with 78-ft. rail there would be considerable difficulty in making emergency replacements with small section gangs. The necessity for such replacements should be at infrequent intervals. Methods of handling should be devised similar to expedients used where lining of track requires more than the ordinary small section force.

The elimination of 135 joints and 36 joints per mile for 78-ft. and 45-ft. rail lengths, respectively, will produce better riding and more easily maintained track with less strain on rolling equipment. In continuous welding of rail there would be an appreciable saving in the number of joints to be welded. The benefits from these sources alone would more than offset many of the objections to longer rail.

Conclusions

The Subcommittee feels that the economies of 45-ft. and 78-ft. lengths of rails have been developed to the extent that present data makes possible, and it is recommended this subject be discontinued.

Appendix I

(7) CONTINUOUS WELDING OF RAIL

Collaborating with Committee 5—Track and Special Committee on Stresses in Railroad Track

J. C. Patterson, Chairman, Subcommittee; J. B. Akers, W. J. Backes, H. A. Cassil, W. A. Duff, F. W. Gardiner, F. M. Graham, C. S. Kirkpatrick, B. R. Kulp, G. M. Magee, Wm. Michel, C. E. Morgan, John V. Neubert, E. E. Oviatt, G. A. Phillips, B. H. Prater, G. R. Smiley, J. C. Wallace, Louis Yager.

The general plans for the investigation as outlined on page 389, Volume 39 of the Proceedings (1938) are being carried out. A large number of etch tests, hardness surveys metallographic studies of metal structures, drop and bend tests, tensile, fatigue and impact tests have been made, including rolling load tests on eighteen welded joints. Details and results of the tests as far as developed will be presented by Dr. H. F. Moore, in charge of the Rails Investigation, University of Illinois, Urbana, Ill., in his report.

Beneficial results from the tests so far conducted are indicated by improvements in two of the welding processes under investigation.

It is planned to continue the tests outlined to a conclusion during next year.

This is a progress report and it is recommended that the subject be continued.

Appendix J

(8) SERVICE TESTS OF VARIOUS TYPES OF JOINT BARS

Robert Faries, Chairman, Subcommittee; W. J. Backes, M. M. Backus, C. B. Bronson, W. A. Duff, F. S. Hewes, C. W. Johns, W. H. Kirkbride, G. M. Magee, Ray McBrian, John V. Neubert, W. H. Penfield, P. Petri, G. A. Phillips, R. T. Scholes, J. E. Willoughby, W. P. Wiltsee, Louis Yager.

As previously reported, the test joints were applied during the early part of June, 1937, on 112-lb. rail, between Toluca, Ill., and Ancona, in the westbound track of the Illinois division of the Atchison, Topeka & Santa Fe Railway, and during the latter part of July, 1937, on 131-lb. rail, between Valparaiso, Ind., and Wanatah, in the eastbound track of the Fort Wayne division of the Pennsylvania Railroad.

Measurements have been made by the field forces and in this connection Dr. A. N. Talbot, under whose direction they are working, reports as follows:

During the year observational tests have been made of the following kinds: Rail surface middle ordinate of 34½ in., vertical mid-ordinate and lateral mid-ordinate of joint bars, profile of rail at joint, profile of fishing surface of bar, rail batter, fit of bar, bolt tension, out-to-out distance between bars at three points in length, joint gap, besides observations of appearance of wear and something of variations in rail fishing hei ht.

Necessarily, measurements have been made on only a portion of the joints and the number of joints taken has varied with such matters as the time required for making the test. To illustrate, on the A.T.&S.F. track with 270 joints on each of the 9 one-mile stretches, about 25 percent have been measured for rail surface ordinate (droop of joint) and out-to-out distances, about 12 percent for rail profile, rail batter, and fit of bar, and between 2 and 3 percent for tension in bolts and bar profiles, while the short job of measurement of joint gap has covered all the joints. Somewhat similar proportions of the joints have been taken in the work on the 12 half-mile stretches of the Pennsylvania Railroad.

The measurements of rail gaps (taken in summer and winter, a quick job) will be useful in learning the variation in movements and in bunching for the different types of rail joint. Most of the other measurements will be used in determining the rate of wear and the keeping of surface as time goes on. Bar profile refers to both fit and wear. Measuring tension in bolts, requiring about six minutes to a bolt (three sets of readings), is unquestionably a most important item, and the information derived should be very valuable. An increase in the number of joints measured for bolt tension should be made in the future.

Attention may well be called to the need of increasing the number of joints to receive all the measured observations. The traffic and wear on these tracks is still so small that observations taken on other joints for the next year or two will give a useful basis for comparison in later years.

New measuring instruments have been designed and built for use on these tests. The new rail-surface profile indicator permits measurements to be made over a distance of 40 in. at a joint. The bar-profile indicator gives measurement on the top, bottom and lateral surfaces of the bar for both four-hole and six-hole bars. The nut-rotation gage indicates how much a nut may have been turned. Another bolt-tension gage has been made.

Notes of general observations on the joints have been made, such as the appearance of wear of rail at the joint, both as compared with it away from the joint and as compared with end hardening and rail treatment on the north and south lines of rail. As

these and other observations are not yet conclusive, no conclusions can now be made on such matters.

The tension in bolts in the test on the Pennsylvania Railroad that was measured in November, 1937, has again been taken and about four additional joints in each section have had bolt-tension measurements made. The measurement in October, 1938, shows that these bolts average about one-third less tension than they had in November, 1937. A loss of this kind is to be expected because of some wear of the bar and rail and because the bar and rail have been pulled closer to each other through the action of traffic. The average tension per bolt in the several sections now ranges from 7,000 to 12,000 lb. (with 25,000 lb. on one type of bar), which presumably, is ample for the proper action of the joints. Recent measurements show that some joints have less than 5,000 lb. tension in one or more bolts. Usually the bolt with low tension is in a joint in which the other bolts show a fairly satisfactory amount of tension. In one of the sections in which bolt-tension measurements have been made on one-quarter of the joints, two joints were found to have low tension in all six of the bolts. In another section two joints had low tension in all four of the bolts.

This is submitted as a progress report and it is recommended that the subject be continued.

Appendix K

(9) INVESTIGATE THE ADVISABILITY OF STRAIGHTENING BENT AND KINKED RAIL FOR REUSE IN MAIN LINE

C. B. Bronson, Chairman, Subcommittee; J. E. Armstrong, W. C. Barnes, W. J. Burton, H. R. Clarke, Robert Faries, B. Herman, F. S. Hewes, W. H. Kirkbride, C. S. Kirkpatrick, B. R. Kulp, Wm. Michel, C. E. Morgan, John V. Neubert, E. E. Oviatt, P. Petri, A. N. Reece, J. C. Ryan, Barton Wheelwright, Louis Yager.

This being a new assignment, it was first advisable to determine through a questionnaire what practices were in use. Of the 28 replies received, 17 indicated that no work was being done or device used for straightening bent or kinked rails. Four roads were gagging bent rails after removal from track, in the regulation straightening press. Experience from 2 to 30 years indicates no damage to the rails.

The remaining seven roads have used track jacks and rail benders of various types to straighten rails both in and out of track, with experience extending from a few months to seven years and report no breakages, except in cases where the rail may be defective for some cause or another. The bulk of the work of straightening bent rails in track is concentrated largely on three reporting roads.

From the replies, and subsequent field investigations by the subcommittee, it was evident that a sharp distinction should be made between bent rails—which are of the so-called surface-bent type, and kinked rails—those damaged by improperly counterbalanced locomotives, etc.

Field observations on two representative roads, where a large amount of straightening was being done, showed that no attempt was made to straighten the kinked rails. The work was all confined to the removal of surface bends together with a certain amount of line bends as an incidental matter. Kinked rails were weeded out and replaced. Kinked rails were those with the downward and inward bend in the head, buckled web and reverse bend in the base.

Physical damage to rails by the removal of bends, either by gagging or the use of rail benders, both in and out of track, has been gone into; a contact having been made with the Rails Investigation to learn of any experience gained, as well as other sources of test data. Tests have proved that gagging does not introduce a change of any consequence in the physical properties of rails, and, as this operation is even more severe than the slow bend methods of the track rail benders, a similar conclusion is warranted for rails straightened by this method. Experience extending over many years indicates that the so-called surface and line-bent rails can be restraightened without damage and that such rails are re-usable for main line service as the engineer in charge of such matters may designate.

The general practice with kinked rails appears, from the studies made, to be the removal of such rails from main track and their relegation to side tracks, or else scrapped, not necessarily because of damage in a physical sense, but due to the roughness of such rails for continued use in main line service. While some roads have intimated that track rail benders are being used to remove kinks from rails (not bends but kinks), the experience of the subcommittee, and the data gathered does not support this viewpoint.

As the subcommittee is not in a position to conduct on its own initiative any extensive tests as to the physical damage which might be done to rails through kinking from improper counterbalance or other sources, the committee suggests that roads equipped with laboratory facilities, and having kinked rails to work on, might conduct tensile, deep-etch, and other tests on portions of the kinked and unkinked rails for comparative data. Laboratory studies made thus far and reported by the Rails Investigation show that rail steel can be badly over-stressed several times without starting a fatigue crack.

The subcommittee's conclusions are as follows:

1. That bent rails—the so-called surface bent type—may be restraightened and reused for such service as the engineer in charge may designate.

2. That the physical damage is slight, if any, from the effects of removal of bends in rails.

3. That kinked rails—those due to improper counterbalance or other causes—are not and probably cannot be restraightened for main line use.

4. That the physical damage to kinked rails has not been investigated by the subcommittee, though evidence through the Rails Investigation shows that rails can be badly over-stressed a number of times without starting of a fatigue crack.

5. That railroads interested in the possible physical damage to kinked rails might use their laboratory facilities to determine through tensile and etch-tests, or more extensive tests of various types, what the relationship is between the kinked and unkinked portions of rails.

This is submitted as a final report and it is recommended that the subject be discontinued.

Appendix L

(10) SPECIFICATIONS FOR RELAYER RAIL

E. E. Oviatt, Chairman, Subcommittee; W. J. Backes, W. C. Barnes, H. A. Cassil, Robert H. Ford, F. W. Gardiner, B. Herman, F. S. Hewes, C. W. Johns, Maro Johnson, B. R. Kulp, A. H. Morrill, John V. Neubert, W. H. Penfield, P. Petri, G. A. Phillips, J. C. Ryan, R. T. Scholes, G. R. Smiley, C. P. Van Gundy, Barton Wheelwright, J. E. Willoughby, Louis Yager.

The assignment of the revision of the Specifications for Relayer Rail was transferred from the Track committee to the Rail committee in the spring of 1937. Since that time, the committee has been endeavoring to work up a revised set of specifications. It was early determined that these specifications would not be used for the selling or purchase of relayer rail, but only by the railroad managements for classifying and determining the use of relayer rail.

Tentative specifications were drawn up, and after considerable correspondence and consideration it was quite evident that it would be impossible to make up specifications for the use of relayer rail that would be acceptable to a majority of the members of the committee. This was due to the fact that the use of relayer rail varied considerably on the various railroads and depended to a great extent on the financial condition of the railroad at the particular time that the rail was to be used.

It therefore became apparent that even if a compromise specification should be adopted by the committee, it would probably not be used by the members of the Association and would therefore be superfluous material in the Manual which would not be used by the members.

In view of this, the committee recommends that the present specifications for relayer rail for various uses, contained in the Manual on pages 5–21 and 5–22, be eliminated from the Manual.

This is submitted as a final report and it is recommended that the subject be discontinued.

REPORT OF SPECIAL COMMITTEE ON STRESSES IN RAILROAD TRACK

A. N. Talbot, *Chairman;*
C. B. Bronson,
W. J. Burton,
W. C. Cushing,
Robert Faries,
C. W. Gennet, Jr.,
F. M. Graham,
H. E. Hale,
F. S. Hewes,
J. B. Jenkins,
George W. Kittredge,
P. M. LaBach,
F. R. Layng,
J. de N. Macomb,
G. M. Magee,
John V. Neubert,
W. H. Penfield,
G. J. Ray,
W. M. Dawley, *Vice-Chairman;*
Albert Reichmann,
H. R. Safford,
F. E. Turneaure,
J. E. Willoughby,
Louis Yager,

Committee.

To the American Railway Engineering Association:

The Special Committee on Stresses in Railroad Track, co-operating with the committee of the American Society of Civil Engineers and with the Association of American Railroads, presents the following report of progress:

The efforts and time of the staff of the committee during the past year have been largely devoted to the continuance of projects previously under way and the reduction and analysis of tests already made. Enumeration and discussion of some of these matters may be found in the report of the committee in the last Proceedings (Vol. 39, 1938, page 399). A discussion presented before the convention by the chairman is given in the same volume (page 857). A description of tests made on the Pennsylvania Railroad in 1937 is there given with various views, sample records, some preliminary results, and other data. This discussion also included further results from measurements on the welded track of the Delaware & Hudson Railroad and the Bessemer & Lake Erie Railroad and some preliminary results of the Service Tests of Various Types of Joint Bars. Information on the program and work of the service tests may be found under the report of Committee 4—Rail, Appendix J of the 1938 Proceedings.

Test Data Being Correlated

The large amount of data of the tests of track on the Pennsylvania Railroad has been reduced and is now being correlated and analyzed and prepared for publication. These tests are discussed in some detail in the above mentioned references and further details will not be given here. It may be said, however, that the many variables present in the action of even excellent track and motive power at high speeds have made the interpretation of the effect of the various factors difficult. Certain limitations of the measuring equipment, such as number of gages on any one joint and their clearance, the number of joints of a given type that can be tested and other elements have also contributed to the difficulties of analysis of the data. However, the work is being carried forward and a report is being prepared.

Some laboratory tests were made on the joints used in the track tests on the Pennsylvania Railroad. These laboratory tests were necessary for use in the reduction of the data of the field tests. The tests were also useful in themselves as a criterion of the value or the effects of the variations in the condition, the section, or other features of the field tests. The actual bars and rail ends tested in the field were used for the laboratory tests, and other conditions of the field tests were simulated as closely as feasible.

Bulletin 409, February, 1939.

Field tests were made again during the summer on the welded track of the Bessemer & Lake Erie Railroad and the Delaware & Hudson Railroad, and it is probable that a set of winter readings will be taken in the near future. It is desired to place on record here that the death of H. S. Clarke, engineer of maintenance of the Delaware & Hudson Railroad, was indeed a great loss to the railroad and the Association. Mr. Clarke, who had been the foremost proponent of continuously welded track construction, was responsible for the large mileage of such track on his own road, and had co-operated with the committee to the fullest extent in the tests made.

Service Test of Joint Bars

In co-operation with Subcommittee 8 on Service Tests of Various Types of Joint Bars of Committee 4—Rail, observational tests have been continued on the 12 half-mile stretches of track on the Pennsylvania Railroad and the nine mile stretches on the Atchison, Topeka & Santa Fe Railway. As noted in the report of the Committee on Rail, observations and measurements made on the joints in track include the following: Rail surface profile, vertical and lateral mid-ordinate of the joint bar, profile of fishing surface, rail batter, fit of bar, out-to-out distance between bar at three points in the length and near the top and bottom of the bar, and tension in bolts, at two or more times during the year. Some of the observations may be expected to give results of interest soon.

The rolling-load testing machine designed for testing rail joints was completed this year, and a series of tests has been run to check its operation, power requirements, speed and general suitability. Although these tests will supplement the service tests being made in the field, the main value of the apparatus will lie in the investigation of special problems. As at present operated, a negative bending moment is applied equal to one-half of the positive moment used. Special instruments have been designed for use in connection with the tests.

At various times during the year assistance and advice has been given to railway companies and others on the planning of tests or the interpretation of test data on special problems. Of special interest have been the data of tests on the New York, New Haven & Hartford Railroad, the Illinois Central Railroad and the Chicago, Burlington & Quincy Railroad.

Considerable study was given to the subject of strain indicating and recording equipment of an electrical nature with a view toward the possibility of the acquisition of such equipment. Members of the staff obtained considerable experience with this type of equipment in making the track tests on the Pennsylvania Railroad the previous year.

It is planned to continue the work along the lines of the general program assigned.

The Special Committee on Stresses in Railroad Track,

A. N. Talbot, *Chairman.*

REPORT OF SPECIAL COMMITTEE ON COMPLETE ROADWAY AND TRACK STRUCTURE

JOHN E. ARMSTRONG, *Chairman;*
A. E. BOTTS,
JOHN FOLEY,
C. J. GEYER,
JOHN V. NEUBERT,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Classification of railways (Appendix A). Progress report.
2. Complete roadway and track for various loads and traffic densities (Appendix B). Progress report.

THE SPECIAL COMMITTEE ON COMPLETE ROADWAY AND TRACK STRUCTURES,
JOHN E. ARMSTRONG, *Chairman.*

Appendix A

(1) CLASSIFICATION OF RAILWAYS

Under this assignment it was at first thought that there should be developed for railway main tracks a classification based upon the individual wheel loads, the total annual tonnage and the speeds of trains passing over them.

The effect on track of specific locomotive wheel loads at various speeds or, conversely, the type of track required for such locomotive wheel loads at various speeds, may be t be determined for different types of locomotives by their owners. Car wheel loads, whatever they may be, pass generally over any class of main track, but their effect is, in substantial part, dependent upon the speed of movement. It appears, therefore, that for the purposes of this report the individual locomotive and car wheel loads may be disregarded and the classification of railway main tracks based upon the total annual tonnage and the speeds of trains passing over them.

Any number of classes of main tracks might be set up by definition. It is suggested, however, that three classes may be sufficient, viz:

1. Main tracks handling large total tonnage per annum, or handling either freight or passenger trains, or both, at high average speeds between stops.
2. Main tracks handling medium total tonnage per annum, and handling neither freight nor passenger trains at high average speeds between stops.
3. Main tracks handling small total tonnage per annum and handling both freight and passenger trains at low average speeds between stops.

In order to place more definite values upon these general statements it is suggested:

1. That more than 12,500,000 tons per annum is large total tonnage, that average speeds of 40 miles or more per hour between stops are high speeds for freight trains, and that average speeds of 60 miles or more per hour between stops are high speeds for passenger trains.
2. That from 5,000,000 to 12,500,000 tons per annum is medium total tonnage, that average speeds between 25 and 40 miles per hour between stops are not high speeds for freight trains, and that average speeds between 40 and 60 miles per hour between stops are not high speeds for passenger trains.

Bulletin 409, February, 1939.

3. That 5,000,000 tons or less per annum is small total tonnage, that average speeds of 25 miles or less per hour between stops are low speeds for freight trains, and that average speeds of 40 miles or less per hour between stops are low speeds for passenger trains.

In line with the foregoing there is submitted the following:

Tentative Classification of Railway Main Tracks

Class A—A railway main track—

1. Which carries a total (including locomotives) of more than 12,500,000 tons per annum, or—
2. Over which freight trains are normally operated at average speeds of 40 miles or more per hour between stops, or—
3. Over which passenger trains are normally operated at average speeds of 60 miles or more per hour between stops.

Class B—A railway main track—

1. Which carries a total (including locomotives) of more than 5,000,000 and not more than 12,500,000 tons per annum, or—
2. Over which freight trains are normally operated at average speeds of more than 25 and less than 40 miles per hour between stops, or—
3. Over which passenger trains are normally operated at average speeds of more than 40 and less than 60 miles per hour between stops.

Class C—A railway main track—

1. Which carries a total (including locomotives) of not more than 5,000,000 tons per annum, or—
2. Over which freight trains are normally operated at average speeds of not more than 25 miles per hour between stops, or—
3. Over which passenger trains are normally operated at average speeds of not more than 40 miles per hour between stops.

Recommendations

That the foregoing Tentative Classification of Railway Main Tracks be accepted as a progress report for discussion, criticisms and suggestions, and that this subject be re-assigned for further consideration in the light of such discussion, criticisms and suggestions.

Appendix B

(2) COMPLETE ROADWAY AND TRACK STRUCTURE FOR VARIOUS LOADS AND TRAFFIC DENSITIES

In line with the Tentative Classification of Railway Main Tracks in Appendix "A" of this report, there is submitted herewith a Tentative Schedule of Classes of Complete Roadway and Track Structure under AREA Recommended Practice.

The three classes of complete roadway and track structure must not be regarded as definitely fixed and mutually exclusive as to details. For example, although 131-lb. R.E. rail is indicated for only Class "A" roadway and track structure, it is quite possible that under some conditions it may be economical for Class "B" roadway and track struc-

ture. Similarly, 90-lb. R.A.–A. rail under some conditions may be economical for Class "A" as well as for Class "B" and Class "C" roadway and track structure.

More unfavorable conditions than average, such as steep gradients, sharp curvature, tunnels and others which are not referred to in the Tentative Classification of Railway Main Tracks, may make economical, in whole or in part, a higher class of complete roadway and track structure than that indicated by tonnage and speeds alone. Similarly, more favorable conditions than average may make economical, in whole or in part, a lower class of complete roadway and track structure than that indicated by tonnage and speeds alone. Such unfavorable and favorable conditions, however, should be treated as special cases, and the track and roadway structure should be provided according to the specific requirements.

Having in mind the many variations in local conditions other than annual tonnages and speeds of trains, it is suggested that the several Schedules of Classes of Complete Roadway and Track Structure should be regarded either as applicable to average conditions, or as indicative rather than as absolute in so far as their respective details are concerned.

These schedules are based upon AREA Recommended Practices. When materials other than those noted are used they should be in each case at least the equivalent of those noted. In the lower ranges of Class "C" main tracks, however, the equivalent of 90-lb. R.A.–A. rail and fastenings is not required. Materials as available may be used in accordance with actual requirements.

Recommendations

That the accompanying Tentative Schedule of Classes of Complete Roadway and Track Structure under AREA Recommended Practice be accepted as a progress report for discussion, criticisms and suggestions, and that this subject be re-assigned for further consideration in the light of such discussion, criticisms and suggestions.

Tentative Schedule of Classes of Complete Roadway and Track Structure Under AREA Recommended Practice

1939

ITEM	CLASS "A"	CLASS "B"	CLASS "C"	MANUAL REFERENCE	
				Item	Page
Roadway					
General	Specifications	Specifications	Specifications	1-401	1-27
Width at Subgrade	As required	As required	As required	1-402-A	1-34
Slopes	As required	As required	As required	1-402-B	1-35
Slope Protection	As required	As required	As required	1-602	1-65
Surface Drainage	As required	As required	As required	1-503	1-43
Sub-surface Drainage	As required	As required	As required	1-504	1-46
Ballast					
Sub-ballast					
Material	As available	As available	As available		45 & 2-15
Ballast or Top Ballast					
Material					
Stone	Specifications	Specifications	Specifications		2-1 & 2-15
Slag	Specifications	Specifications	Specifications		2-13 & 2-15
Prepared Gravel					
More than 20% crushed	Specifications	Specifications	Specifications		2-7 & 2-15
20% and less crushed	Specifications	Specifications	Specifications		2-7 & 2-15
Pit Run Gravel	See Note "A"	Specifications	Specifications		2-11 & 2-15
Cinders	See Note "A"	See Note "A"	As available		2-15
Ballast Section					
With Sub-ballast	1(a) to 1(e) incl.	1(e) to 1(i) incl.	1(i) to 1(m) incl.		2-17
	3(a) to 3(d) incl.	3(d) to 3(i) incl.	3(i) to 3(p) incl.		2-18
Without Sub-ballast	2(a) to 2(n) incl.	2(n) to 2(l) incl.	2(l) to 2(p) incl.		2-17
	4(a)	4(a) to 4(e) incl.	4(e) to 4(m) incl.		2-18
Cross Ties					
General	Specifications	Specifications	Specifications		3-1
Kind	Best available	Best available	Best available	3-101	3-1
Size	5 or 4	5 or 4	5, 4 or 3	3-301	3-2 & 3-15
Length	9 ft., 8 ft. 6 in., or 8 ft.	8 ft. 6 in., or 8 ft.	8 ft.	3-301	3-2 & 3-15
Number per 39 ft. rail	25 to 23	25 to 23	23 or less		3-15
Untreated	Class "U"	Class "U"	Class "U"	3-605	3-4
Treated	Class "T"	Class "T"	Class "T"	3-605	3-4
Machined as required	Specifications	Specifications	Specifications		3-9 & 3-20
Treatment	Specifications	Specifications	Specifications		17-1 & 17-3
Process					
Lowry	Specifications	Specifications	Specifications		17-3 & 17-6
Rueping	Specifications	Specifications	Specifications		17-3 & 17-7
Preservative					
Creosote	Specifications	Specifications	Specifications		17-13
Creosote-Coal Tar Solution	Specifications	Specifications	Specifications		17-14

TENTATIVE SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE UNDER AREA RECOMMENDED PRACTICE—Continued
1939

ITEM	CLASS "A"	CLASS "B"	CLASS "C"	MANUAL REFERENCE	
				Item	Page
TIE PLATES					
Material					
Wrought Iron	Specifications	Specifications	Specifications		5-11
Soft Steel	Specifications	Specifications	Specifications		5-1
Medium Steel	Specifications	Specifications	Specifications		5-1
High Carbon Steel	Specifications	Specifications	Specifications		See Note "B"
Design					
For Wrought Iron					
With 131-lb. R. E. rail	See Note "B"	See Note "A"	See Note "A"		See Note "B"
With 112-lb. R. E. rail	See Note "B"	See Note "B"	See Note "A"		See Note "B"
With 100-lb. R. E. rail	See Note "B"	See Note "B"	See Note "B"		See Note "B"
With 90-lb. R.A.-A. rail	See Note "A"	See Note "B"	See Note "B"		See Note "B"
For Soft Steel					
With 131-lb. R. E. rail	See Note "B"	See Note "A"	See Note "A"		See Note "B"
With 112-lb. R. E. rail	See Note "B"	See Note "B"	See Note "A"		See Note "B"
With 100-lb. R. E rail	See Note "B"	See Note "B"	See Note "B"		See Note "B"
With 90-lb. R.A.-A. rail	See Note "A"	See Note "B"	See Note "B"		See Note "B"
For Medium Steel					
With 131-lb. R. E. rail	Plan No. 6—See Note "C"	See Note "A"	See Note "A"		5-5 & 5-10
	Plan No. 5—See Note "D"	See Note "A"	See Note "A"		5-5 & 5-9
	Plan No. 3—See Note "D"	See Note "A"	See Note "A"		5-5 & 5-7
With 112-lb. R. E. rail	Plan No. 4—See Note "D"	Plan No. 4—See Note "D"	See Note "A"		5-5 & 5-8
	Plan No. 2—See Note "D"	Plan No. 2—See Note "D"	See Note "A"		5-5 & 5-6
	See Note "A"	Plan No. 10—See Note "E"	See Note "A"		5-5 & 5-5.3
With 100-lb. R. E. rail	Plan No. 2—See Note "D"	Plan No. 2—See Note "D"	See Note "A"		5-5 & 5-6
	See Note "A"	Plan No. 1C—See Note "E"	Plan No. 1C—See Note "E"		5-5 & 5-5.3
With 90-lb. R.A.-A. rail	See Note "A"	Plan No. 1B—See Note "E"	Plan No. 1B—See Note "E"		5-5 & 5-5.2
	See Note "A"	Plan No. 1A—See Note "E"	Plan No. 1A—See Note "E"		5-5 & 5-5.1
For High Carbon Steel					
With 131-lb. R. E. rail	See Note "B"	See Note "A"	See Note "A"		See Note "B"
With 112-lb. R. E. rail	See Note "B"	See Note "B"	See Note "A"		See Note "B"
With 100-lb. R. E. rail	See Note "B"	See Note "B"	See Note "B"		See Note "B"
With 90-lb. R.A.-A. rail	See Note "M"	See Note "B"	See Note "B"		See Note "B"
HOLD DOWN SPIKES					
Type					
Screw	Specifications	Specifications	See Note "A"		See Note "B"
Cut	Specifications	Specifications	See Note "A"		5-15
Design					
Screw	See Note "B"	See Note "B"	See Note "A"		See Note "B"
Cut	6 in. x 5/8 in.	6 in. x 5/8 in.	See Note "A"		5-17
Number per Tie Plate					
Screw	As required	As required	See Note "A"		See Note "B"
Cut	As required	As required	See Note "A"		See Note "B"

TENTATIVE SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE UNDER AREA RECOMMENDED PRACTICE—Continued

1939

ITEM	CLASS "A"	CLASS "B"	CLASS "C"	MANUAL REFERENCE	
				Item	Page
RAIL					
General	Specifications	Specifications	Specifications		4-1
Section					
131-lb. R. E.	Figure 404	See Note "A"	See Note "A"		4-11
112-lb. R. E.	Figure 403	Figure 403	See Note "A"		4-10
100-lb. R. E.	Figure 402	Figure 402	Figure 402		4-9
90-lb. R. A. -A.	See Note "A"	Figure 401	Figure 401		4-8
Drilling					
131-lb- R. E.	4 or 6 hole	4 or 6 hole	See Note "A"		4-12 & 4-28
112-lb. R. E.	4 or 6 hole	4 or 6 hole	See Note "A"		4-12 & 4-27
100-lb. R. E.	4 or 6 hole	4 or 6 hole	4 or 6 hole		4-12 & 4-26
90-lb. R. A. -A.	See Note "A"	4 or 6 hole	4 or 6 hole		4-12 & 4-25
Length	39 ft.	39 ft.	39 ft.	4-402	4-3
Classification	No. 1	No. 1	No. 1	4-304	4-3
JOINT BARS					
Material					
High Carbon Steel	Specifications	Specifications	Specifications		4-17
Quenched Carbon Steel	Specifications	Specifications	Specifications		4-21
Section					
For 131-lb. R. E. rail	Plan	See Note "A"	See Note "A"		4-28
For 112-lb. R. E. rail	Plan	Plan	See Note "A"		4-27
For 100-lb. R. E. rail	Plan	Plan	Plan		4-26
For 90-lb. R. A. -A. rail	See Note "A"	Plan	Plan		4-25
Length and Punching					
For 131-lb. R. E. rail	36 in. with 6 holes	See Note "A"	See Note "A"		4-28
	24 in. with 4 holes	See Note "A"	See Note "A"		4-28
For 112-lb. R. E. rail	36 in. with 6 holes	36 in. with 6 holes	See Note "A"		4-27
	24 in. with 4 holes	24 in. with 4 holes	See Note "A"		4-27
For 100-lb. R. E. rail	36 in. with 6 holes	36 in. with 6 holes	36 in. with 6 holes		4-26
	24 in. with 4 holes	24 in. with 4 holes	24 in. with 4 holes		4-26
For 90-lb. R. A. -A. rail	See Note "A"	36 in. with 6 holes	36 in. with 6 holes		4-25
	See Note "A"	24 in. with 4 holes	24 in. with 4 holes		4-25
TRACK BOLTS AND NUTS					
General	Specifications	Specifications	Specifications		4-29
Design					
For 131-lb. R. E. rail	1 in. x 6¼ in.	See Note "A"	See Note "A"		4-28 & 4-33
For 112-lb. R. E. rail	1 in. x 6 in.	1 in. x 6 in.	See Note "A"		4-27 & 4-33
For 100-lb. R. E. rail	1 in. x 5½ in.	1 in. x 5½ in.	1 in. x 5½ in.		4-26 & 4-33
For 90-lb. R. A. -A. rail	See Note "A"	1 in. x 5¼ in.	1 in. x 5¼ in.		4-25 & 4-33

TENTATIVE SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE UNDER AREA RECOMMENDED PRACTICE—Continued

1939

ITEM	CLASS "A"	CLASS "B"	CLASS "C"	MANUAL REFERENCE	
				Item	Page
SPRING WASHERS—See Note "F"					
General	Specifications	Specifications	Specifications		4-37
TRACK SPIKES					
General	Specifications	Specifications	Specifications		5-15
Design					
6 in. x 5/8 in.	Plan	Plan	See Note "A"		5-17
5½ in. x 9/16 in.	See Note "A"	Plan	Plan		5-17
Number per tie plate	As required	As required	As required		See Note "B"
ANTI-CREEPERS					
General	Specifications	Specifications	Specifications		See Note "B"
Number per 39 ft. rail	As required	As required	As required		5-18

NOTES:
"A"—This item will not ordinarily be used in this class of Track.
"B"—Recommended Practice not yet determined.
"C"—With double shoulders and screw hold down spikes.
"D"—With or without double shoulders and with or without screw or cut hold down spikes as required.
"E"—With or without double shoulders and without screw or cut hold down spikes as required.
"F"—Spring washers to be used only when Recessed Nuts are not used.

REPORT OF COMMITTEE 3—TIES

JOHN FOLEY, *Chairman;*
R. S. BELCHER,
W. C. BOLIN,
W. H. BRAMELD,
H. F. BROWN,
W. J. BURTON,
R. E. BUTLER,
S. B. CLEMENT,
R. L. COOK,
C. F. FORD,
B. D. HOWE,
N. W. HUTCHISON,
W. S. KING,
C. S. KIRKPATRICK,
H. R. DUNCAN, *Vice-Chairman;*
D. O. LYLE,
A. F. MAISCHAIDER,
W. D. SIMPSON,
SVERRE THORVALDSON,
C. D. TURLEY,
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

(1) Revision of Manual (Appendix A). Recommended as an addition.

(2) Extent of adherence to specifications (Appendix B). Presented as information.

(3) Substitutes for wood ties. Progress in compilation of statistics—no report.

(4) Tie renewal averages and costs per maintained mile (Appendix C). Presented as information.

(5) Proper seasoning of oak ties, with special reference to those grown in southern lowlands. Progress in study—no report.

(6) Investigate and report on the dimensions of ties, and bring up to date the information presented in the 1924 and 1932 Proceedings (Appendix D). Progress report as to lengths presented as information.

THE COMMITTEE ON TIES,
JOHN FOLEY, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

John Foley, Chairman, Subcommittee; W. J. Burton, H. R. Duncan, D. O. Lyle, A. F. Maischaider, C. D. Turley.

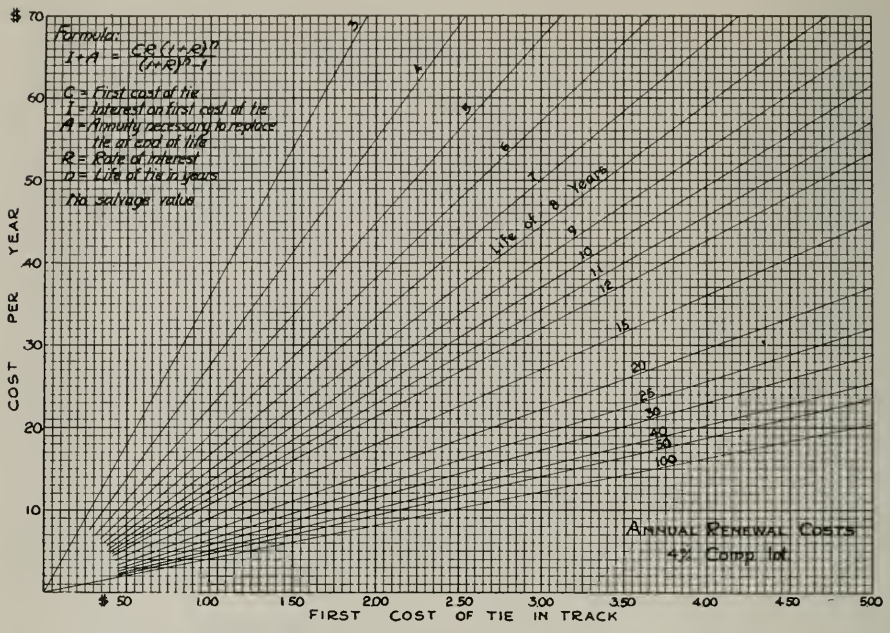
On page 3–15 of the Manual there are formulas for use in determining the capitalization and annual cost of a tie. To obviate the necessity for making extensive calculations whenever comparisons between ties having different first costs or service lives are undertaken, there have been prepared the following diagrams, which are recommended for inclusion in the Manual.

Appendix B

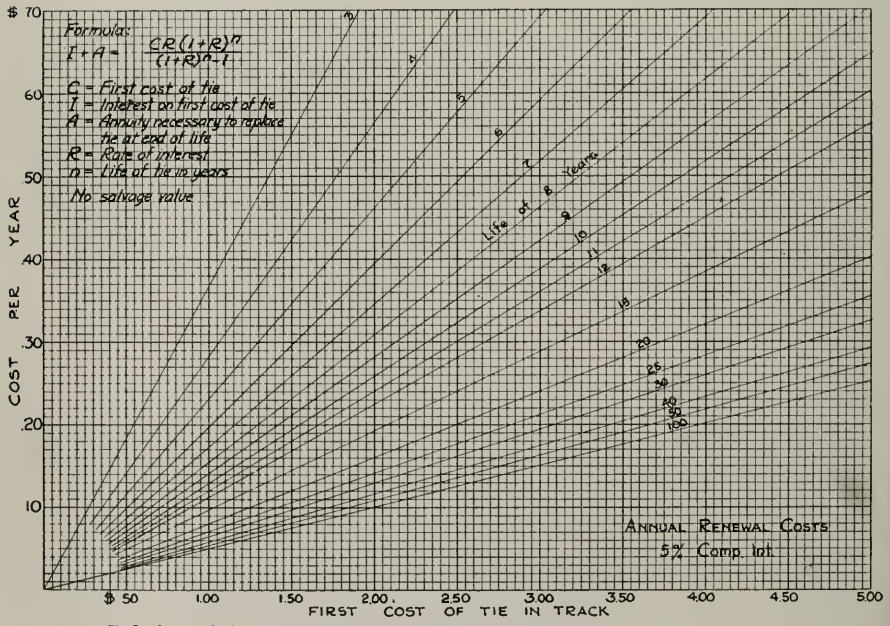
(2) EXTENT OF ADHERENCE TO STANDARD SPECIFICATIONS

H. R. Duncan, Chairman, Subcommittee; R. S. Belcher, W. C. Bolin, W. H. Brameld, H. F. Brown, W. J. Burton, R. L. Cook, C. F. Ford, B. D. Howe, N. W. Hutchison, W. S. King, W. D. Simpson, Sverre Thorvaldson, C. D. Turley.

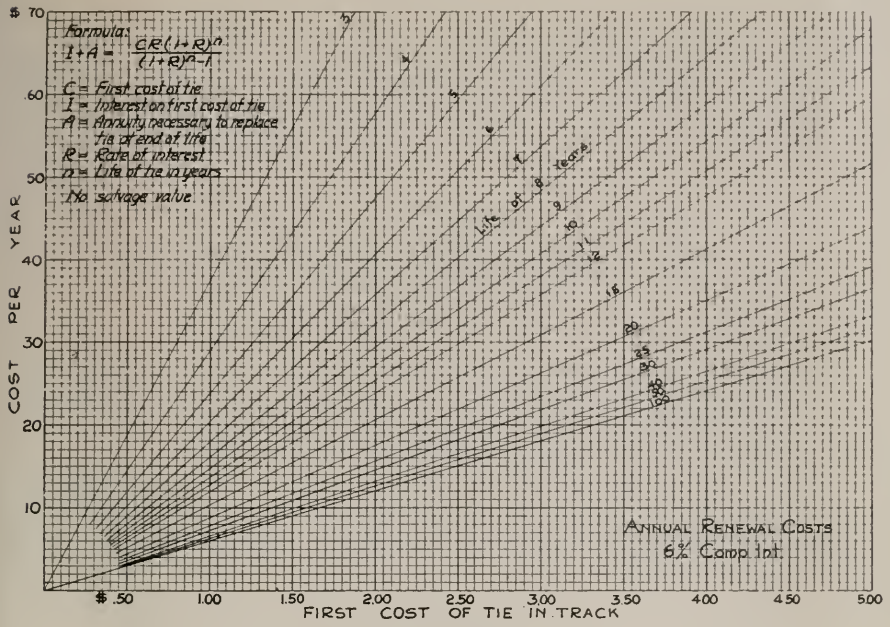
In April and November, 1938, visits were made by the committee as a whole to the seasoning yards of 7 commercial wood-preserving plants in Illinois and Ohio, to observe 2,000,000 ties accepted by 11 railroads. With the exception of 50,000 oak ties taken by one railroad from stocks shipped in from Kentucky and Tennessee, all the ties examined were produced along the lines of the railroads owning them.



Relation of Costs of Ties per Year to First Cost of Ties in Track—
Four Percent Compound Interest.



Relation of Costs of Ties per Year to First Cost of Ties in Track—
Five Percent Compound Interest.



Relation of Costs of Ties per Year to First Cost of Ties in Track—
Six Percent Compound Interest.

Most of the ties were of oak, the remainder being miscellaneous other hardwoods such as beech, birch, gum, maple, etc. Nearly all the ties were sawed. Where they were not, their manufacture was poor.

All the yards visited were in good condition, though in two of them some vegetation was present and there was evidence that at times too much of it is permitted. In general the stacking of ties was satisfactory. At only one plant were many of the stacks in poor order, the ties being layered so close that in frequent cases their sides were in contact with each other. In another, uneven vertical stacking was brought about by locating the stringer ties in from the ends of the layer ties as an accommodation to drivers of anti-splitting devices.

All the ties seen had been ironed to control splitting, but too often, because of the indiscriminate application of the irons and the insertion of too few irons, their use did not prove fully effective.

Substandard ties did not characterize any of the lots examined, but in three cases many ties were accepted in sizes not warranted by their dimensions, and throughout these stacks ties accepted when unmistakably decayed were frequently noted. The commonest fault of those who inspected the substandard ties wherever they were observed was the acceptance of ties ½ in. thinner than the standard thickness, especially in Sizes 1, 2 and 3.

In two cases it was possible to determine from the identifying brands on the ties that the acceptances by inexperienced men during the period, early in 1937, when production was being stimulated and inspection forces expanded, had led to the following undesirable results: A greatly increased number of thin ties in Sizes 1, 2 and 3; ties with decayed spots which, apparently, had not been recognized when accepted, but

which were evident after a year's storage; and ties not well manufactured, in that their ends were not even approximately square.

The notable difference in the work of new men and old men demonstrates that capable inspectors are not everywhere readily available and cannot be trained in a day or a week.

Appendix C

(4) TIE RENEWAL AVERAGES AND COSTS PER MAINTAINED MILE

D. O. Lyle, Chairman, Subcommittee; S. B. Clement, N. W. Hutchison.

The statistics of tie renewals herewith (Tables A and B for 1937 and Table C for the past five years and the average of them) are the data as reported to the Interstate Commerce Commission by U. S. railroads and to this Association by the Canadian roads. They were given advance publication in Bulletin 404, June–July, 1938.

Errors in the data received from the Interstate Commerce Commission prompt the suggestion that tie-renewal figures sent to Washington by the accounting department be checked by the engineering department of each railroad to insure correctness in columns 2, 3, 4, 5, and 6 of Table A.

Appendix D

(6) INVESTIGATE AND REPORT ON THE DIMENSIONS OF TIES, AND BRING UP TO DATE THE INFORMATION PRESENTED IN THE 1924 AND 1932 PROCEEDINGS

W. J. Burton, Chairman, Subcommittee; W. C. Bolin, W. H. Brameld, H. F. Brown, R. E. Butler, S. B. Clement, R. L. Cook, C. S. Kirkpatrick, A. F. Maischaider, W. D. Simpson, Sverre Thorvaldson.

Your committee has elected to report on the length of crossties this year.

Present Practice

Standard-gage ties of three lengths are in use at the present time:

8 ft., used generally west of the Mississippi river.

8½ ft., used generally east of the Mississippi river and by certain western railroads for lines of heavy traffic.

9 ft., used in only a few cases to provide greater support.

Crosstie lengths have been handed down from the early days of railroads, apparently with more regard for precedent and commercial-timber lengths than for suitability as a part of a structure called upon to perform certain functions to the best advantage. Increases in demands on tracks brought about by increasing loads and speeds have served to focus attention on tie length.

Functions of Crosstie

The crosstie performs these functions:

(a) Holds the rails to gage;

(b) Distributes the concentrated load from the rail base and tie plate over a much larger area of ballast;

TABLE A

CROSS TIES LAID IN REPLACEMENT - CLASS I STEAM ROADS, UNITED STATES AND LARGE CANADIAN ROADS

Calendar year ended December 31, 1937

Road	Wooden ties untreated (U)		Wooden ties treated (T)		Ties other than wood(S) & secondhand reapplied	Total ties applied	Miles of maintained tracks (item 24)	Estimated total gross ties in all maintained tracks (item 25)	Equated gross ton-miles a (thousands)
	Number	Average cost*	Number	Average cost*					
1	2	3	4	5	6	7	8	9	10
NEW ENGLAND REGION:									
Bangor & Aroostook	164 446	$0.55	-	-	-	164 446	828.70	2 372 077	1 487 582
Boston & Maine	36 952	0.80	300 588	$1.59	-	337 540	3 279.00	9 706 000	1) 645 225
Canadian Nat.Lines in New Eng.	8 873	0.61	18 986	1.32	-	27 859	250.21	768 600	535 402
Canadian Pacific (lines in Me.)	-	-	29 554	1.26	-	29 554	213.19	614 880	1 252 525
Canadian Pacific (lines in Vt.)	-	-	5 714	1.03	-	5 714	161.91	421 834	565 824
Central Vermont	7 498	0.93	53 090	1.53	-	60 588	533.92	1 616 000	2 436 440
Maine Central	144 788	0.71	142 028	1.66	-	286 816	1 249.41	3 789 600	3 471 974
New York Connecting	-	-	5 876	1.47	-	5 876	25.98	82 861	33, 419
New York,New Haven & Hartford	-	-	339 108	1.20	-	339 108	4 339.59	13 127 152	20 010 329
Rutland	-	-	16 834	1.21	*2 764	19 638	500.05	1 552 500	1 551 100
GREAT LAKES REGION:									
Ann Arbor	-	-	41 164	1.32	-	41 164	408.09	1 224 300	1 415 294
Cambria & Indiana	13 861	0.90	7 680	2.01	-	21 541	83.70	166 600	135 939
Delaware & Hudson	1 016	1.27	156 786	2.14	(S) 16 142	173 944	1 462.87	4 451 507	8 869 944
Delaware,Lackawanna & Western	-	-	136 676	1.46	*11 582	148 258	1 395.07	6 945 703	17 138 760
Detroit & Mackinac	29 298	0.53	8 206	0.70	-	37 504	294.57	882 618	284 121
Detroit & Toledo Shore Line	-	-	1 859	1.76	* 33	16 892	151.58	462 730	765 947
Erie (Incl.CA&E)	-	-	440 923	1.47	-	440 923	4 906.36	14 333 877	33 078 960
Grand Trunk Western	133	0.59	292 866	1.44	-	292 999	1 949.67	6 160 957	8 158 324
Lehigh & Hudson River	-	-	10 975	2.03	*1 320	12 295	120.90	318 500	627 025
Lehigh & New England	80	0.39	16 903	1.38	-	16 983	285.51	854 766	823 104
Lehigh Valley	-	-	63 089	1.42	-	63 089	2 820.52	8 318 072	10 347 606
Monongahela	-	-	44 058	1.89	-	44 058	242.17	700 282	947 400
Montour	958	1.22	6 878	2.35	-	7 836	77.93	217 829	184 291
New Jersey & New York	738	0.64	2 943	0.85	-	3 681	56.97	164 314	226 664
New York Central	5 343	1.38	2 154 934	1.36	*18 017	2 178 294	22 216.58	68 627 018	150 473 120
New York,Chicago & St.Louis	-	-	260 143	1.31	-	260 143	2 527.41	7 923 437	16 976 284
New York,Ontario & Western	-	-	48 969	1.31	-	48 969	896.85	2 542 946	2 486 795
New York,Susquehanna & Western	-	-	19 916	1.31	-	19 916	233.24	676 992	440 961
Pere Marquette	-	-	487 943	1.64	-	487 943	2 838.12	8 583 608	10 997 929
Pittsburgh & Lake Erie	74	1.00	66 491	1.74	-	66 565	537.08	2 807 296	4 688 727
Pittsburg & Shawmut	32 259	1.15	10 061	2.06	* 806	43 126	121.57	339 059	176 200
Pittsburgh & West Virginia	43 174	1.36	19 799	2.29	*21 679	84 652	198.09	575 930	949 632
Pittsburg,Shawmut & Northern	35 229	0.99	-	-	-	35 229	223.71	657 070	265 564
Wabash	-	-	488 986	1.52	-	488 986	3 241.11	10 051 092	19 557 828
CENTRAL EASTERN REGION:									
Akron, Canton & Youngstown	36 907	1.31	-	-	-	36 907	213.51	614 964	470 193
Baltimore & Ohio	5 481	0.75	1 268 655	1.42	(S) 4	1 274 140	10 790.44	30 661 344	66 070 255
Bessemer & Lake Erie	360	0.79	133 265	2.17	(S) 33	133 658	494.95	1 534 894	4 612 295
Central R.R.of New Jersey	-	-	92 357	1.72	-	92 357	1 494.20	4 206 744	7 926 658
Chicago & Eastern Illinois	-	-	118 891	1.42	-	118 891	1 429.61	4 433 140	6 421 120
Chicago & Illinois Midland	-	-	13 701	1.59	-	13 701	181.64	498 872	940 100
Chicago,Indpls.& Louisville	16 000	0.77	63 073	1.12	*23 016	102 089	823.94	2 525 997	3 878 608
Detroit,Toledo & Ironton	2 730	0.64	76 734	1.24	-	79 464	610.44	1 758 067	1 625 906
Elgin,Joliet & Eastern	55	0.93	184 143	1.53	*9 767	193 965	853.98	2 704 793	3 331 976
Illinois Terminal	2 783	0.76	59 963	1.21	*5 936	68 682	652.12	1 536 380	1 628 982
Long Island	-	-	70 704	1.55	-	70 704	833.86	2 472 498	6 885 471
Missouri-Illinois	74 855	0.76	6 208	1.28	-	81 063	239.01	745 600	253 461
Pennsylvania	2 004	0.87	2 250 263	1.60	1 142	2 252 409	21 521.02	60 257 229	169 134 366
Penna.-Reading Seashore Lines	-	-	19 914	2.10	-	19 914	662.20	1 824 001	1 774 199
Reading Co.	130	1.09	125 536	1.86	-	125 666	3 092.67	8 371 547	10 345 647
Staten Island Rapid Transit	-	-	7 327	1.75	-	7 327	111.74	279 790	406 321
Western Maryland	65 603	0.92	166 018	1.56	-	231 621	1 194.49	3 440 137	5 912 150
Wheeling & Lake Erie	1 472	1.02	177 913	1.40	*11 017	190 402	848.18	2 546 149	4 211 769
POCAHONTAS REGION:									
Chesapeake & Ohio	622	0.56	336 796	1.14	-	337 418	5 104.75	15 698 833	50 822 441
Norfolk & Western	-	-	179 404	1.09	*17 472	196 876	4 116.08	13 379 848	38 120 086
Richmond,Fred.& Potomac	34 914	0.82	80 068	1.63	* 24	115 006	377.16	1 077 700	3 634 890
Virginian	109 411	0.72	82 154	1.36	*1 504	193 069	850.72	2 649 142	7 045 [illegible]
SOUTHERN REGION:									
Alabama Great Southern	6 867	1.04	93 659	1.43	-	100 526	540.88	1 706 357	3 073 814
Atlanta & West Point	10 391	1.17	17 292	0.94	-	27 683	141.26	432 995	1 272 294
Western Ry.of Alabama	1 825	1.19	28 218	1.02	-	30 043	182.18	552 461	[illegible]
Atlantic,Birmingham & Coast	34 586	0.77	108 332	1.12	-	142 918	799.13	2 307 900	1 696 579
Atlantic Coast Line	737 498	0.85	31 996	1.32	-	769 494	6 844.37	19 819 473	21 905 543
Central of Georgia	1 315	0.77	340 801	0.86	-	342 116	2 507.60	7 045 000	7 542 718
Charleston & Western Carolina	66 633	0.99	-	-	-	66 633	425.43	1 241 685	856 150
Cincinnati,New Orleans & Tex.Pac.	28	0.96	84 251	1.52	-	84 279	774.37	2 409 418	6 877 367
Clinchfield	76 156	0.70	47 718	1.44	-	123 874	596.91	1 206 676	2 561 134
Columbus & Greenville	3 382	0.59	41 518	1.20	-	44 900	201.77	639 201	392 567
Florida East Coast	246 996	0.78	-	-	-	246 996	1 149.54	3 812 710	4 261 152
Georgia R.R.	57 648	1.23	3 855	1.68	-	61 503	430.33	1 318 934	1 447 456
Georgia & Florida	120 251	0.67	-	-	-	120 251	452.53	1 221 831	487 710
Georgia,Southern & Florida	41 694	0.98	-	-	-	41 694	471.40	1 482 218	1 300 793
Gulf & Ship Island	919	0.96	53 401	1.01	*316	54 636	111.05	960 837	516 685
Gulf,Mobile & Northern	78 925	0.64	239 821	1.10	*340	299 086	940.24	2 976 677	2 560 24[illegible]
Illinois Central	74 429	0.70	1 031 919	1.04	*1 021	1 107 369	7 798.71	23 805 365	[illegible] 50 429 [illegible]
Yazoo & Miss.Valley	101 116	0.72	223 696	1.04	-	324 812	2 134.32	6 542 536	[illegible]
Louisville & Nashville	37 042	1.04	759 402	1.27	-	796 444	6 955.17	19 827 764	17 006 411
Mississippi Central	4 111	0.52	59 019	1.04	-	63 130	168.09	532 479	252 731
Mobile & Ohio	313 144	0.75	33 339	1.27	*2 110	354 653	1 219.52	3 803 440	5 018 909
Nashville,Chattanooga & St.Louis	1 482	0.46	173 617	1.14	-	177 099	1 551.37	4 567 860	5 772 160
New Orleans & Northeastern	2 170	0.88	34 816	1.38	-	36 986	281.47	874 799	1 316 250
Norfolk Southern	357 279	0.74	-	-	-	357 279	973.20	2 978 188	1 461 632
Northern Alabama	21 672	0.89	25 068	1.53	-	46 740	118.67	372 292	269 571
Seaboard Air Line	700 936	0.88	398 841	1.00	-	1 099 777	5 179.06	16 289 704	19 240 097
Southern Ry.	1 328 636	0.99	758 227	1.46	-	2 086 863	8 661.55	27 157 268	39 159 949
Tennessee Central	85 486	0.67	-	-	-	85 486	337.21	1 021 066	777 400

* These are storekeepers' average costs of ties charged out and used. They are not the actual costs or the prices paid for ties purchased during the period.

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TABLE A

CROSS TIES LAID IN REPLACEMENT - CLASS I STEAM ROADS, UNITED STATES AND LARGE CANADIAN ROADS

Calendar year ended December 31, 1937

Road	Wooden ties untreated (U)		Wooden ties treated (T)		Ties other than wood(S) & secondhand reapplied	Total ties applied	Miles of maintained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Equated gross ton-miles a (thousands)
	Number	Average cost	Number	Average cost					
1	2	3	4	5	6	7	8	9	10
NORTHWESTERN REGION:									
Chicago & North Western	100 737	$0.55	1 705 373	$0.96	-	1 806 110	12 151.80	35 876 748	37 946 855
Chicago Great Western	100 536	0.98	237 516	1.39	-	338 052	1 898.06	5 599 528	9 119 125
Chicago,Milwaukee,St.Paul & Pac.	764 368	0.50	1 202 439	1.29	-	1 966 807	14 285.44	42 885 735	46 118 129
Chicago,St.Paul,Minpls.& Omaha	118 424	0.68	307 665	1.04	-	426 089	2 851.86	6 670 143	7 474 626
Duluth,Missabe & Iron Range	39 004	0.76	92 960	1.43	-	131 964	1 097.52	3 295 292	4 693 783
Duluth,South Shore & Atlantic	131 687	0.61	11	1.35	-	131 698	532.22	1 511 899	785 419
Duluth,Winnipeg & Pacific	58 277	0.60	6 495	1.47	-	64 772	211.59	634 770	511 953
Great Northern	69 112	0.52	1 125 326	1.21	*19 503	1 213 941	9 886.13	30 637 029	37 151 638
Green Bay & Western	67 914	0.69	32 780	1.56	-	100 694	286.30	824 064	468 636
Lake Superior & Ishpeming	45 104	0.64	275	2.12	-	45 379	234.83	704 490	238 733
Minneapolis & St.Louis	255 588	0.86	82 641	1.33	-	338 229	1 696.92	5 122 847	3 164 547
Minneapolis,St.Paul & S.S.Marie	496 170	0.59	347 053	1.22	-	843 223	5 000.45	14 728 014	10 720 916
Northern Pacific	39 793	0.50	1 133 646	1.00	(S) 26	1 173 465	9 085.50	26 376 355	28 563 475
Spokane International	71 874	0.45	-	-	-	71 874	194.18	549 453	228 900
Spokane,Portland & Seattle	125 401	0.66	62 409	1.40	-	187 810	1 085.71	3 308 580	3 214 476
CENTRAL WESTERN REGION:									
Alton R.R.	316 484	1.22	39 796	1.74	*363	356 643	1 532.21	4 616 962	6 979 919
Atchison,Topeka & Santa Fe	6 597	0.65	2 432 278	1.15	-	2 438 875	19 574.46	59 447 635	79 845 048
Chicago,Burlington & Quincy	-	-	1 845 530	1.25	*133 927	1 979 457	12 360.90	38 188 987	47 056 974
Chicago,Rock Island & Pacific	96	0.29	1 223 359	0.92	-	1 223 451	9 403.78	27 977 334	(
Chicago,Rock Island & Gulf	-	-	60 474	1.15	*b 793	67 267	750.79	2 334 470	(38 359 102
Colorado & Southern	16 483	0.40	61 090	1.20	*25 210	102 783	898.00	2 694 000	3 113 686
Denver & Rio Grande Western	10 802	0.31	445 160	1.07	H 190 438	646 400	3 319.70	10 357 494	12 082 162
Denver & Salt Lake	2 048	0.76	121 798	1.28	-	123 846	343.00	956 920	894 945
Fort Worth & Denver City	-	-	70 217	1.06	*18 508	88 725	960.66	2 889 639	3 192 018
Nevada Northern	26 728	0.80	-	-	-	26 728	190.89	547 860	135 734
Northwestern Pacific	59 053	0.77	-	-	-	59 053	459.74	1 338 447	1 080 087
Southern Pacific Co.- Pacific Lines	126 668	0.75	1 017 254	1.21	-	1 143 922	12 431.39	37 459 822	74 878 256
Toledo,Peoria & Western	849	0.65	109 333	1.43	-	110 182	276.05	874 526	741 553
Union Pacific	26 650	0.66	2 319 317	1.03	-	2 345 967	13 170.39	37 194 649	82 941 076
Utah Ry.	6 248	0.70	7 228	2.15	* 24	13 500	87.18	274 048	186 779
Western Pacific	388 364	0.69	193 760	1.37	-	582 124	1 480.60	4 596 000	8 070 388
SOUTHWESTERN REGION:									
Burlington-Rock Island	-	-	14 796	0.59	-	14 796	213.36	667 817	561 451
Gulf Coast Lines:									
Beaumont,Sour Lake & Western	200	0.64	15 154	1.12	-	15 354	139.85	416 400	(
New Orleans,Texas & Mexico	3 093	0.69	36 567	1.12	-	39 660	226.99	693 900	(5 342 401
St.Louis,Brownsville & Mexico	-	-	84 817	1.06	-	84 817	752.17	2 275 200	(
San Antonio,Uvalde & Gulf	467	0.57	44 585	1.15	-	45 052	360.87	1 040 300	(
International-Great Northern	-	-	151 627	1.01	-	151 627	1 496.88	4 482 100	5 882 597
Kansas City Southern	-	-	166 976	1.03	-	166 976	1 261.38	3 996 650	4 996 883
Kansas,Oklahoma & Gulf	759	0.54	72 473	1.01	-	73 232	357.16	1 071 540	895 905
Louisiana & Arkansas	34 314	0.52	106 704	0.81	-	141 018	714.38	2 257 025	1 906 345
Louisiana,Arkansas & Texas	68 645	0.58	6 392	0.97	-	75 037	249.64	746 050	459 950
Midland Valley	244	0.61	44 673	1.03	-	44 917	389.33	1 168 000	410 080
Missouri & Arkansas	153 893	0.44	-	-	-	153 893	357.73	1 114 427	436 606
Missouri-Kansas-Texas Lines	23 082	0.72	483 639	0.95	-	506 721	4 100.89	12 914 700	15 000 812
Missouri Pacific	151 901	0.72	1 610 059	1.12	-	1 761 960	9 041.71	27 990 000	44 293 316
Oklahoma City-Ada-Atoka	27 962	0.51	5 667	0.64	-	33 629	144.32	432 960	86 089
St.Louis-San Francisco	239 719	0.69	1 104 333	1.08	-	1 344 052	6 324.83	20 537 092	22 219 992
St.Louis,San Francisco & Texas	17 062	0.69	25 649	0.97	-	42 711	258.33	814 768	460 325
St.Louis Southwestern Lines	-	-	386 497	1.08	*47 731	414 228	1 926.62	6 107 850	8 914 922
Texas & New Orleans	92	0.93	754 705	0.92	-	754 797	5 704.75	15 584 333	19 852 152
Texas & Pacific	54	0.43	217 713	1.00	-	217 767	2 483.81	7 339 129	13 058 147
Texas Mexican	109	0.25	54 676	1.15	-	54 785	206.05	593 424	298 424
CANADIAN ROADS:									
Canadian National	4 259 476	0.58	2 181 320	1.28	-	6 440 796	30 181	86 380 345	72 531 837
Canadian Pacific	1 858 108	0.53	1 804 280	1.23	-	3 662 388	22 268	63 096 127	56 089 723
Temiskaming & Northern Ontario	130 960	0.62	287	1.89	-	131 247	635.19	1 808 700	1 520 724

a Wainhaider formula.
H Narrow gauge and secondhand ties.
b Tunnel ties.
* Secondhand ties.

Note: Compiled from annual reports of Class I railways to the Interstate Commerce Commission.

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TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) ON LEADING RAILROADS IN THE UNITED STATES AND CANADA

Calendar year ended December 31, 1937

Note: All figures are exclusive of bridge & switch ties

Road	Miles of maintained track occupied by wooden cross ties (Col.8-Table A)	Average number of wooden cross ties per mile of maintained track	Total number of wooden cross ties renewed 1937	Number of wooden cross ties renewed per mile of maintained track	Weighted average cost per wooden cross tie	Cost of wooden cross tie renewals per mile of maintained track	Per cent wooden cross tie renewals to all ties in track	Equated gross ton-miles per mile of maintained track	Cost of wooden cross tie renewals per thousand equated gross ton-miles
1	2	3	4	5	6	7	8	9	10
NEW ENGLAND REGION:									
Bangor & Aroostook	828.70	2 802	164 446	198	$0.55	$109	0.9	1 795 079	$0.061
Boston & Maine	3 279.00	2 960	337 540	103	1.51	155	3.5	4 162 618	.037
Canadian Nat.Lines in New Eng.	250.21	3 072	27 859	111	1.09	122	3.6	2 139 807	.057
Canadian Pacific (lines in Me.)	213.19	2 804	29 554	139	1.26	175	4.8	5 875 149	.030
Canadian Pacific (lines in Vt.)	123.31	3 140	5 734	46	1.01	46	1.4	4 506 403	.010
Central Vermont	533.92	3 064	60 588	113	1.46	166	3.7	4 563 347	.036
Maine Central	1 249.41	3 033	286 816	230	1.18	271	7.6	2 778 891	.097
New York Connecting	25.98	3 185	5 876	226	1.47	332	7.1	12 833 000	.026
New York,New Haven & Hartford	4 339.59	3 025	339 108	78	1.20	93	2.6	4 611 110	.020
Rutland	500.05	3 103	36 874	74	1.27	94	2.4	3 101 910	.030
GREAT LAKES REGION:									
Ann Arbor	408.09	3 000	41 104	101	1.32	133	3.4	3 468 093	.038
Cambria & Indiana	63.70	2 615	21 541	338	1.29	437	12.9	2 134 050	.205
Delaware & Hudson	1 462.87	3 043	157 802	108	2.14	230	3.5	6 003 385	.038
Delaware, Lackawanna & Western	2 395.07	2 900	167 758	70	1.39	97	2.4	7 153 849	.014
Detroit & Mackinac	294.37	2 996	38 304	127	.57	72	4.2	964 135	.075
Detroit & Toledo Shore Line	151.58	3 053	16 59	111	1.76	196	3.6	5 053 087	.039
Erie (Incl.-Chgo.& Erie)	4 906.36	2 921	440 923	90	1.47	132	3.1	6 742 057	.020
Grand Trunk Western	1 949.67	3 160	292 999	150	1.44	217	4.8	4 184 494	.052
Lehigh & Hudson River	120.90	2 633	10 975	91	2.03	184	3.4	5 103 598	.036
Lehigh & New England	285.51	2 994	16 983	59	1.37	82	2.0	2 873 920	.028
Lehigh Valley	2 820.52	2 949	63 079	22	1.42	32	0.8	5 795 955	.005
Monongahela	242.17	2 892	44 058	182	1.69	343	9.3	3 912 458	.088
Montour	77.93	2 795	7 836	101	2.21	224	3.6	4 931 233	.045
New Jersey & New York	56.97	2 884	3 681	65	.81	52	2.2	3 978 655	.013
New York Central	22 216.58	3 089	2 160 247	97	1.36	132	3.1	6 773 010	.019
New York,Chicago & St.Louis	2 547.41	3 135	280 143	111	1.31	147	3.5	6 716 870	.025
New York,Ontario & Western	830.85	2 935	48 707	55	1.31	72	1.9	2 772 810	.026
New York,Susquehanna & Western	233.24	2 903	19 916	85	1.31	112	2.9	1 890 589	.059
Pere Marquette	2 838.12	3 024	487 943	172	1.64	281	5.7	5 875 075	.073
Pittsburgh & Lake Erie	937.08	2 996	96 853	71	1.76	124	2.4	5 003 550	.025
Pittsburg & Shawmut	141.57	2 797	4 100	349	1.37	476	12.5	1 452 477	.328
Pittsburgh & West Virginia	198.09	2 907	62 971	318	1.65	524	10.9	4 793 942	.109
Pittsburg,Shawmut & Northern	223.71	2 937	35 249	157	.99	155	5.4	1 276 492	.122
Wabash	3 241.11	3 101	488 986	151	1.52	229	4.9	6 034 299	.038
CENTRAL EASTERN REGION:									
Akron,Canton & Youngstown	213.51	2 880	36 907	173	1.31	226	6.0	2 202 206	.103
Baltimore & Ohio	10 750.04	2 842	1 274 138	118	1.42	168	4.2	6 143 543	.027
Bessemer & Lake Erie	494.95	3 101	133 825	270	2.17	585	8.7	9 359 111	.063
Central R.R.of New Jersey	1 494.20	2 815	92 357	62	1.72	106	2.2	5 304 951	.020
Chicago & Eastern Illinois	1 429.63	3 101	138 893	97	1.22	109	3.1	4 492 855	.024
Chicago & Illinois Midland	104.74	3 083	13 701	85	1.59	138	2.7	5 958 144	.023
Chicago,Indpls.& Louisville	823.94	3 066	79 073	96	1.05	101	3.1	4 707 391	.021
Detroit,Toledo & Ironton	610.44	2 880	79 404	130	1.22	159	4.5	2 803 498	.060
Elgin,Joliet & Eastern	653.98	3 167	184 198	281	1.53	431	8.8	5 901 703	.085
Illinois Terminal	652.12	3 000	92 846	98	1.19	114	3.2	4 174 277	.052
Long Island	33.76	2 745	70 704	85	1.55	131	2.9	8 257 347	.016
Missouri-Illinois	259.01	3 120	81 063	339	.80	272	10.9	1 060 462	.256
Pennsylvania	21 521.02	2 800	2 252 267	105	1.60	168	3.7	7 859 031	.021
Pennsylvania-Reading Seashore Lines	665.20	2 738	39 094	59	2.10	123	2.1	2 667 467	.046
Reading Company	3 052.67	2 742	125 886	41	1.86	76	1.5	5 354 541	.014
Staten Island Rapid Transit	101.74	2 750	7 327	72	1.75	126	2.6	3 993 719	.032
Western Maryland	1 174.49	2 880	231 621	194	1.38	267	6.7	4 149 528	.064
Wheeling & Lake Erie	848.18	3 002	179 385	211	1.39	293	7.0	4 850 113	.061
POCAHONTAS REGION:									
Chesapeake & Ohio	3 104.75	3 075	337 418	96	1.14	75	2.1	9 916 733	.008
Norfolk & Western	4 316.08	3 100	179 404	42	1.09	45	1.3	8 832 108	.005
Richmond,Fred.& Potomac	377.16	2 857	114 982	305	1.38	422	10.7	9 637 528	.044
Virginian	850.72	3 114	191 365	225	1.00	224	7.2	8 281 262	.027
SOUTHERN REGION:									
Alabama Great Southern	548.88	3 109	100 526	183	1.40	256	5.9	5 600 193	.046
Atlanta & West Point	141.28	3 065	27 683	196	1.03	201	6.4	(3 933 389	.047
Western Ry.of Ala.	132.18	3 038	30 143	165	1.03	169	5.4	(	
Atlanta,Birmingham & Coast	799.13	2 888	142 918	179	1.04	186	6.2	2 123 029	.088
Atlantic Coast Line	6 844.37	2 905	769 494	112	.87	98	3.9	3 200 520	.031
Central of Georgia	2 807.60	2 809	342 116	139	.86	118	4.9	3 002 145	.039
Charleston & West.Carolina	425.43	2 919	50 633	157	.99	155	5.4	2 012 434	.077
Cincinnati,New Orleans & Tex.Pac.	774.37	3 111	84 279	109	1.52	166	3.5	8 881 242	.019
Clinchfield	396.93	3 040	123 874	312	.98	307	10.3	6 457 390	.048
Columbus & Greenville	201.47	3 168	44 900	223	1.15	257	7.0	1 960 485	.131
Florida East Coast	1 349.54	2 869	246 996	183	.78	143	6.4	3 156 744	.045
Georgia R.R.	430.33	3 065	81 503	141	1.26	180	4.7	3 343 595	.053
Georgia & Florida	452.53	2 700	120 253	266	.67	179	9.8	1 077 741	.166
Georgia,Southern & Florida	471.40	3 144	41 694	88	.98	87	2.8	2 759 001	.031
Gulf & Ship Island	311.85	3 081	34 320	174	1.00	175	5.7	1 701 732	.103
Gulf,Mobile & Northern	940.24	3 168	298 746	318	.98	310	10.0	2 722 968	.114
Illinois Central	7 798.71	3 052	1 106 348	142	1.02	144	4.6	(5 076 983	.028
Mexico & Mississippi Valley	2 14.32	3 056	124 402	292	.94	275	5.0	(	
Louisville & Nashville	6 955.17	2 851	796 444	115	1.26	144	4.0	5 406 972	.027
Mississippi Central	163.09	3 148	63 130	386	1.01	388	11.9	1 203 546	.323
Mobile & Ohio	1 219.52	3 160	352 543	289	.81	235	9.1	4 115 477	.057
Nashville,Chattanooga & St.Louis	1 551.27	2 944	177 099	114	1.13	129	3.9	3 741 297	.035
New Orleans & Northeastern	281.47	3 108	36 986	131	1.35	178	4.2	4 076 342	.038
Norfolk Southern	373.20	3 060	357 279	367	.74	272	12.0	1 522 433	.178
Northern Alabama	118.87	3 124	46 740	393	1.24	486	12.6	2 292 780	.214
Seaboard Air Line	5 379.06	3 028	1 099 777	204	.93	189	6.8	3 577 409	.053
Southern Ry.	8 601.55	3 128	2 086 803	240	1.17	280	7.7	4 510 709	.062
Tennessee Central	337.21	3 028	85 406	254	.67	169	8.4	2 203 388	.077

TABLE 8

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) ON LEADING RAILROADS IN THE UNITED STATES AND CANADA

Calendar year ended December 31, 1937

Note: All figures are exclusive of bridge & switch ties

Road	Miles of maintained track occupied by wooden cross ties (Col.8-Table A)	Average number of wooden cross ties per mile of maintained track	Total number of wooden cross ties renewed 1937	Number of wooden cross ties renewed per mile of maintained track	Weighted average cost per wooden cross tie	Cost of wooden cross tie renewals per mile of maintained track	Per cent wooden cross tie renewals to all ties in tracks	Equated gross ton-miles per mile of maintained tracks	Cost of wooden cross tie renewals per thousand equated gross ton-miles
1	2	3	4	5	6	7	8	9	10
NORTHWESTERN REGION:									
Chicago & North Western	12 151.80	2 952	1 806 110	149	$0.93	$139	5.0	3 122 735	$0.044
Chicago Great Western	1 898.00	2 950	338 052	178	1.27	225	6.0	4 804 445	.047
Chicago, Milwaukee, St.Paul & Pac.	14 285.44	3 002	1 966 807	138	.98	135	4.6	3 248 331	.042
Chicago, St.Paul, Minpls.& Omaha	2 251.86	2 962	426 089	189	.74	178	6.4	3 319 343	.054
Duluth, Missabe & Iron Range	1 097.50	3 003	131 963	120	1.23	148	4.0	4 476 735	.033
Duluth, South Shore & Atlantic	522.22	2 841	131 698	247	.61	152	8.7	1 473 741	.103
Duluth, Winnipeg & Pacific	211.59	3 000	64 772	306	.69	210	10.2	2 419 552	.087
Great Northern	9 886.13	3 029	1 194 438	121	1.17	141	3.9	3 737 356	.038
Green Bay & Western	286.30	2 880	100 936	352	.77	271	14.2	1 934 87.	.209
Lake Superior & Ishpeming	214.81	3 000	45 179	193	.68	145	6.4	1 010 641	.143
Minneapolis & St.Louis	1 690.92	3 019	335 269	199	.98	195	6.6	1 864 877	.104
Minneapolis, St.Paul & Ste.Marie	5 000.45	2 945	843 223	169	.85	143	5.7	2 143 590	.066
Northern Pacific	9 085.50	2 993	1 173 439	129	.98	126	4.4	3 143 553	.040
Spokane International	194.18	2 830	71 874	370	.45	168	13.1	1 178 803	.143
Spokane, Portland & Seattle	1 085.71	3 047	187 810	173	.87	150	5.7	2 760 713	.054
CENTRAL WESTERN REGION:									
Alton R.R.	1 534.21	3 013	356 280	233	1.27	296	7.7	4 545 451	.065
Atchison, Topeka & Santa Fe	19 574.46	3 037	2 438 875	125	1.14	143	4.1	4 079 042	.035
Chicago, Burlington & Quincy	12 300.90	3 008	1 845 530	149	1.23	186	4.8	3 805 074	.049
Chicago, Rock Island & Pacific	9 403.78	2 975	1 223 451	130	.76	119	4.4		
Chicago, Rock Island & Gulf	7.0.79	3 109	60 474	81	1.15	93	2.6	3 777.521	.024
Colorado & Southern	97.00	3 000	77 573	80	1.03	82	2.9	3 467 356	.026
Denver & Rio Grande Western	3 319.70	3 120	455 962	137	1.00	145	4.4	3 937 534	.040
Denver & Salt Lake	343.13	3 094	143 846	295	1.27	502	12.9	4 896 498	.126
Fort Worth & Denver City	960.66	3 008	70 217	73	1.00	76	2.4	3 322 797	.023
Nevada Northern	190.89	2 870	26 728	140	.80	112	4.9	711 059	.158
Northwestern Pacific	459.74	2 911	59 053	128	.77	99	4.4	2 349 361	.042
Southern Pacific Co.- Pac.Lines	12 421.39	3 013	1 143 322	92	1.16	107	3.1	3 043 321	.035
Toledo, Peoria & Western	276.05	3 168	110 182	399	1.42	568	12.0	2 880 300	.211
Union Pacific	13 170.39	2 824	2 345 967	178	1.03	183	6.3	6 297 541	.029
Utah Ry.	87.18	2 685	13 479	155	1.48	228	5.8	3 748 545	.061
Western Pacific	1 480.60	2 969	582 124	393	.92	361	13.2	5 55 755	.066
SOUTHEASTERN REGION:									
Burlington-Rock Island	215.36	3 130	14 796	69	.59	41	2.2	2 851 473	.016
Gulf Coast Lines:									
Beaumont, Sour Lake & Western	139.85	2 977	15 354	110	1.11	122	3.7		
New Orleans, Texas & Mexico	226.99	3 057	39 660	175	1.08	190	5.7	3 910 043	.031
St.Louis, Brownsville & Mexico	752.17	3 025	84 017	113	1.06	120	3.7		
San Antonio, Uvalde & Gulf	160.87	2 883	45 052	145	1.14	142	4.3		
International-Great Northern	1 496.88	2 994	151 627	101	1.01	102	3.4	3 349 906	.026
Kansas City Southern	1 261.38	3 168	126 976	132	1.03	137	4.2	3 961 441	.035
Kansas, Oklahoma & Gulf	357.16	3 000	73 212	205	1.01	206	6.8	4 508 414	.046
Louisiana & Arkansas	714.38	3 159	141 018	197	.71	145	6.2	2 668 531	.054
Louisiana, Arkansas & Texas	246.64	3 025	75 037	304	.82	187	10.1	1 804 864	.100
Midland Valley	367.33	3 000	44 917	115	1.03	119	3.8	1 053 297	.113
Missouri & Arkansas	357.73	3 115	153 893	430	.44	191	11.8	1 420 490	.134
Missouri-Kansas-Texas Lines	4 100.89	3 149	506 721	124	.94	116	3.9	3 057 941	.038
Missouri Pacific	9 041.71	3 096	1 761 960	195	1.09	212	6.3	4 898 776	.043
Oklahoma City-Ada-Atoka	144.34	3 000	33 649	233	.93	213	7.8	596 515	.206
St.Louis-San Francisco	6 524.85	3 145	1 344 052	206	1.01	209	6.5	4 409 441	.064
St.Louis-San Francisco & Texas	256.33	3 134	42 711	165	.86	142	5.2	1 781 926	.080
St.Louis Southwestern Lines	1 926.62	3 170	366 497	190	1.08	205	6.0	4 627 234	.044
Texas & New Orleans	5 704.75	2 732	754 797	132	.92	122	4.8	3 479 934	.035
Texas & Pacific	2 485.91	2 944	217 787	88	1.00	88	3.0	5 253 136	.017
Texas Mexican	406.05	2 880	94 785	266	1.15	306	9.2	1 448 309	.211
CANADIAN ROADS:									
Canadian National	30 181	2 868	6 140 796	213	0.82	174	7.1	2 403 228	-
Canadian Pacific	22 268	2 833	3 662 388	164	0.87	143	5.8	2 518 819	.060
Temiskaming & Nor.Ontario	635.19	2 900	131 247	207	0.67	138	7.2	2 354 124	.059

Col.3 derived by dividing Col.7 Table A by Col.8 of same table.
Col.4 is total of Columns 2 and 4 of Table A.
Col.5 derived by dividing totals of Columns 2 and 4 of Table A, by Col.8 of same table.
Col.6 is weighted average of costs shown in Columns 3 and 5 of Table A.

Note: Compiled from annual reports of Class I Railways to the Interstate Commerce Commission

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Bureau of Railway Economics
Washington, D.C.
June, 1938.

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TABLE C

NUMBER AND AGGREGATE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF WOODEN CROSS TIE RENEWALS TO TOTAL WOODEN CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1933 to 1937, inclusive

Note: All figures are exclusive of bridge and switch ties.

Road	Number of wooden cross tie renewals per mile of maintained track						Aggregate cost of wooden cross tie renewals per mile of maintained track						Per cent wooden cross tie renewals to all ties in tracks					
	1933	1934	1935	1936	1937	5 year average	1933	1934	1935	1936	1937	5 year average	1933	1934	1935	1936	1937	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	189	204	190	188	198	194	$126	$127	$106	$102	$109	$114	6.6	7.1	6.7	6.6	6.9	6.8
Boston & Maine	75	118	64	71	103	86	118	198	94	99	155	133	2.6	4.1	2.2	2.4	3.5	3.0
Canadian Nat.Lines in New Eng.	87	85	92	135	111	102	122	114	137	163	122	132	2.8	2.8	3.0	4.4	3.6	3.3
Canadian Pacific (lines in Me.)	170	182	153	148	139	158	242	252	186	181	175	207	5.9	6.3	5.3	5.1	4.8	5.5
Canadian Pacific (lines in Vt.)	134	68	53	42	46	69	192	98	86	53	48	91	3.5	2.0	1.5	1.1	1.4	2.0
Central Vermont	184	193	153	137	113	156	292	261	213	195	166	225	6.0	6.3	5.0	4.5	3.7	5.1
Maine Central	167	192	187	219	230	199	162	216	204	254	271	221	5.5	6.3	6.2	7.2	7.6	6.6
New York Connecting	131	257	213	317	226	229	238	411	330	469	332	356	4.1	8.0	6.7	9.9	7.1	7.2
New York,New Haven & Hartford	73	62	71	86	78	74	108	85	93	107	93	97	2.5	2.2	2.3	2.8	2.6	2.5
Rutland	147	129	109	88	74	109	174	134	129	111	94	128	4.9	4.2	3.5	2.8	2.4	3.6
GREAT LAKES REGION:																		
Ann Arbor	130	106	106	110	101	111	193	141	142	142	133	150	4.3	3.6	3.6	3.7	3.4	3.8
Cambria & Indiana	348	341	237	285	338	310	312	296	211	277	437	307	12.7	12.4	8.8	10.8	12.9	11.5
Delaware & Hudson	139	103	106	93	108	110	297	206	223	199	230	231	4.6	3.4	3.5	3.1	3.5	3.6
Delaware,Lackawanna & Western	53	108	92	127	70	90	72	128	128	161	97	117	1.8	3.7	3.2	4.4	2.4	3.5
Detroit & Mackinac	114	101	132	119	121	119	77	58	70	68	72	70	3.8	3.4	4.4	4.0	4.2	4.0
Detroit & Toledo Shore Line	100	83	134	129	111	111	166	137	235	224	196	192	3.3	2.7	4.4	4.2	3.6	3.6
Erie (Incl.CAE)	106	104	90	88	90	96	154	144	131	124	132	137	3.7	3.6	3.1	3.0	3.1	3.3
Grand Trunk Western	141	152	153	160	150	151	179	190	200	221	217	203	4.5	4.8	4.8	5.1	4.8	4.8
Lehigh & Hudson River	22	21	46	37	91	48	18	40	77	103	184	88	0.9	0.9	1.8	2.2	3.4	1.8
Lehigh & New England	72	75	69	64	59	68	132	127	93	90	82	105	2.4	2.5	2.2	2.1	2.0	2.2
Lehigh Valley	83	66	74	58	22	53	92	94	100	52	32	74	2.1	2.2	2.5	1.3	0.8	1.8
Monongahela	131	153	157	188	102	146	221	278	260	338	343	288	4.5	5.4	5.4	6.5	6.3	5.6
Montour	102	115	103	94	101	103	159	218	194	177	222	194	3.6	4.1	3.7	3.4	3.6	3.7
New Jersey & New York	111	82	70	64	65	78	152	100	99	77	52	96	3.8	2.8	2.4	2.2	2.2	2.7
New York Central R.R.Co.	52	70	71	82	97	74	82	102	96	118	132	106	1.7	2.5	2.3	2.7	3.1	2.5
New York,Chicago & St.Louis	91	84	85	94	111	88	114	131	115	167	142	134	2.0	2.7	2.8	3.0	3.5	2.8
New York,Ontario & Western	90	69	83	51	55	70	107	82	122	67	72	90	3.2	2.4	2.9	1.8	1.9	2.4
New York,Susquehanna & Western	113	130	99	92	85	104	151	170	129	111	112	135	3.9	4.5	3.4	3.1	2.9	3.6
Pere Marquette	118	123	127	142	172	136	149	164	182	214	291	198	3.9	4.1	4.2	4.7	5.7	4.5
Pittsburgh & Lake Erie	35	41	28	51	71	45	73	86	59	102	144	87	1.2	1.4	1.0	1.7	2.4	1.5
Pittsburg & Shawmut	218	260	201	301	348	278	184	241	309	283	476	299	7.9	9.3	10.3	10.8	12.3	10.2
Pittsburgh & West Virginia	114	187	170	208	218	219	96	166	175	267	524	250	3.9	6.5	5.9	10.8	10.9	7.6
Pittsburg,Shawmut & Northern	154	183	174	180	157	170	163	249	157	164	155	178	5.3	6.3	5.9	6.1	5.4	5.8
Wabash	129	130	139	146	151	139	203	190	205	204	229	206	4.1	4.2	4.5	4.7	4.9	4.7
CENTRAL EASTERN REGION:																		
Akron,Canton & Youngstown	171	264	339	194	173	228	186	333	366	240	226	270	6.0	9.2	11.8	6.7	6.0	7.9
Baltimore & Ohio	73	81	91	109	118	94	117	128	148	166	188	118	2.6	2.9	3.2	3.8	4.2	3.4
Bessemer & Lake Erie	151	241	239	260	270	232	264	501	507	554	585	482	4.8	7.8	7.7	8.4	8.7	7.5
Central R.R.of New Jersey	45	33	49	60	62	50	77	54	80	98	106	83	1.6	1.2	1.8	2.1	2.2	1.8
Chicago & Eastern Illinois	62	98	100	75	77	83	96	169	167	131	109	102	3.0	5.2	5.2	4.0	3.4	4.0
Chicago & Illinois Midland	107	94	147	99	75	100	114	90	193	135	135	133	3.9	3.4	4.8	3.2	2.7	3.6
Chicago,Inspls.& Louisville	65	82	97	79	96	84	74	83	101	82	101	88	2.1	2.6	3.2	2.6	3.1	2.7
Detroit,Toledo & Ironton	92	142	155	134	130	131	126	172	193	152	159	160	3.2	4.9	5.4	4.6	4.5	4.5
Elgin,Joliet & Eastern	124	165	176	211	216	178	155	227	242	300	331	251	4.0	5.3	5.7	6.8	6.8	5.7
Illinois Terminal	90	73	85	88	96	86	87	87	88	98	114	95	2.7	2.7	2.8	2.9	3.1	2.8
Long Island	42	54	85	95	89	81	54	103	73	74	131	91	1.4	2.2	2.0	2.0	2.9	2.1
Missouri-Illinois	183	296	421	384	339	325	83	168	381	260	272	233	5.9	9.6	13.4	12.3	10.9	10.4
Pennsylvania R.R.	55	64	57	79	105	73	97	100	89	114	166	114	2.1	2.3	2.0	2.8	3.7	2.6
Penna.-Reading Seashore Lines	4	54	49	46	39	43	9	75	58	68	123	66	0.2	2.1	1.8	1.7	2.4	1.6
Reading Co.	2	35	6	41	41	26	48	60	63	71	76	64	1.1	1.3	1.3	1.5	1.5	1.4
Staten Island Rapid Transit	64	69	48	45	72	60	170	175	110	99	128	134	2.3	2.5	1.8	1.7	2.6	2.2
Western Maryland	180	219	202	226	194	204	244	260	253	294	267	264	6.2	7.6	7.0	7.9	6.7	7.1
Wheeling & Lake Erie	78	63	221	220	211	159	113	85	277	290	295	212	2.6	2.1	7.3	7.3	7.0	5.1
POCAHONTAS REGION:																		
Chesapeake & Ohio	92	94	73	91	66	83	105	104	86	99	75	94	3.0	3.1	2.4	3.0	2.1	2.7
Norfolk & Western	106	90	75	61	42	75	123	102	82	64	45	83	3.4	2.9	2.4	2.0	1.3	2.4
Richmond,Fred.& Potomac	298	344	314	281	305	308	215	260	231	255	422	277	10.4	12.0	11.0	9.9	10.7	10.8
Virginian	205	208	215	220	225	215	225	221	181	236	224	217	6.6	6.7	6.9	7.1	7.2	6.9
SOUTHERN REGION:																		
Alabama Great Southern	243	275	253	217	181	228	255	335	333	276	256	292	6.9	8.9	8.2	7.0	5.9	7.4
Atlanta & West Point	176	151	151	156	196	166	256	223	231	219	201	226	5.8	5.0	4.9	5.1	6.4	5.4
Western Ry. of Alabama	160	120	138	141	165	146	235	173	194	188	169	192	5.6	4.0	4.5	4.6	5.4	4.8
Atlanta,Birmingham & Coast	126	151	156	188	179	160	70	110	106	155	186	125	4.4	5.2	5.6	6.5	6.2	5.6
Atlantic Coast Line	152	145	154	140	112	141	214	116	201	98	104	147	5.2	5.0	5.3	4.8	3.9	4.8
Central of Georgia	116	121	121	120	136	124	79	88	96	104	110	96	4.2	4.3	4.3	4.5	4.9	4.4
Charleston & Western Carolina	157	163	177	172	157	173	157	159	166	166	155	161	6.7	5.6	6.1	5.9	5.4	5.9
Cincinnati,New Orleans & Tex.Pac.	157	163	145	138	109	142	219	235	222	208	166	210	5.0	5.2	4.7	4.4	3.5	4.6
Clinchfield	272	314	304	308	312	322	309	272	274	284	307	289	12.2	10.3	10.0	10.1	10.3	10.6
Columbus & Greenville	219	220	271	209	221	228	176	198	196	210	257	207	6.9	6.9	8.6	6.6	7.0	7.2
Florida East Coast	172	135	141	131	183	152	87	102	102	99	143	107	6.0	4.7	4.9	4.6	6.4	5.3
Georgia R.R.	194	133	110	111	141	138	214	143	148	116	180	160	6.3	4.3	3.6	3.6	4.7	4.5
Georgia & Florida	201	266	278	269	266	256	95	136	148	167	179	145	7.5	9.6	10.3	10.0	9.8	9.2
Georgia,Southern & Florida	83	99	79	84	88	87	54	69	60	67	87	67	2.7	3.6	2.5	2.7	2.8	2.9
Gulf & Ship Island	135	171	152	144	174	155	67	78	100	83	175	111	4.4	5.6	5.0	4.7	5.7	5.1
Gulf,Mobile & Northern (see note)	119	157	207	201	218	200	81	120	177	173	210	172	4.0	5.0	6.5	6.3	10.0	6.4
Illinois Central	95	135	133	144	142	130	91	122	120	137	144	123	3.1	4.4	4.4	4.7	4.6	4.2
Yazoo & Miss.Valley	93	143	149	144	152	132	84	102	109	115	142	110	3.0	4.0	4.9	4.7	5.0	4.3
Louisville & Nashville	109	110	107	110	115	110	147	134	131	135	144	138	3.8	3.8	3.8	3.9	4.0	3.9
Mississippi Central	106	155	218	338	376	239	101	148	145	289	378	212	3.4	4.9	6.9	10.7	11.9	7.6
Mobile & Ohio	210	137	134	147	207	293	131	214	205	209	235	199	7.1	10.0	10.0	10.0	9.1	9.2
Nashville,Chattanooga & St.Louis	229	173	140	118	114	155	236	173	144	129	122	162	7.7	5.9	4.7	4.0	3.9	5.2
New Orleans & Northeastern	185	196	159	137	131	162	162	224	207	172	178	188	6.0	6.3	5.2	4.4	4.2	5.2
Norfolk Southern	284	386	362	280	367	336	150	224	206	161	272	203	10.0	13.6	12.7	9.9	12.0	11.6
Northern Alabama	172	164	177	184	191	179	257	304	267	431	406	348	11.9	11.5	12.1	12.3	12.6	12.1
Seaboard Air Line	204	215	217	226	240	217	135	171	182	183	189	172	6.6	7.7	8.2	7.5	6.8	7.4
Southern Ry.	260	282	273	259	240	263	200	273	244	256	280	251	8.2	9.0	8.7	8.5	7.7	8.4
Tennessee Central	415	325	288	294	254	315	265	242	295	245	169	243	13.2	10.4	9.2	9.7	8.4	10.2

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NUMBER AND AGGREGATE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF WOODEN TIE RENEWALS TO TOTAL WOODEN CROSS TIES IN TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1933 to 1937, inclusive

Note: All figures are exclusive of bridge and switch ties.

Road	Number of wooden cross tie renewals per mile of maintained track						Aggregate cost of wooden cross tie renewals per mile of maintained track						Per cent wooden cross tie renewals to all ties in track					
	1933	1934	1935	1936	1937	5 year average	1933	1934	1935	1936	1937	5 year average	1933	1934	1935	1936	1937	5 year average
NORTHWESTERN REGION:																		
Chicago & North Western	100	116	120	143	149	126	$100	$111	$110	$126	$139	$117	3.4	3.9	4.1	4.8	5.0	4.2
Chicago Great Western	179	194	165	151	178	173	179	209	162	155	225	192	6.1	6.7	5.7	5.1	6....	...
Chicago, Milwaukee, St.Paul & Pac.	133	184	241	212	138	182	131	168	263	211	135	182	4.5	6.2	8.1	7.1	4....	6.1
Chicago, St.Paul, Minpls.& Omaha	152	164	146	167	189	164	111	143	129	151	178	142	5.1	5....	4.9	5.6	6.4	...
Duluth, Missabe & Iron Range	38	62	52	76	120	70	53	92	71	110	140	9...	1.3	2.1	1.8	2....	4.0	...
Duluth, South Shore & Atlantic	153	182	203	223	247	191	70	84	99	126	152	106	3.3	3.9	4.4	4.8	5.3	4.1
Duluth, Winnipeg & Pacific	279	375	369	376	306	339	137	177	193	223	210	188	9.0	12.5	12....	12....	10.2	...
Great Northern	40	110	104	112	121	97	37	115	112	126	141	106	1.2	3.4	3.3	3....	3.9	3....
Green Bay & Western	328	340	417	441	352	376	199	212	322	391	343	293	11.7	12.1	14.8	15....	12.4	12....
Lake Superior & Ishpeming	148	166	198	225	183	190	100	112	147	186	128	116	4....	6.2	7....	8....	6.4	6....
Minneapolis & St.Louis	0	104	131	206	179	147	01	95	110	188	195	131	2.9	3.4	4.5	6....	6....	4....
Minneapolis, St.Paul & S.S.Marie	169	158	179	179	169	171	143	130	146	162	143	145	5.8	5.4	6.1	6.1	5.7	5....
Northern Pacific	97	82	91	122	129	104	105	89	94	126	126	100	3.3	2.6	3.2	4....	4....	3....
Spokane International	263	313	300	341	370	317	112	137	123	153	168	139	9.3	11.1	10.6	12.1	13.1	11....
Spokane, Portland & Seattle	154	142	130	166	173	153	72	68	76	120	150	97	5.1	4.7	4.3	5....	5.7	...
CENTRAL WESTERN REGION:																		
Alton R.R.	2....	263	247	240	233	237	202	293	266	237	296	269	6.7	8.7	8.2	7.9	7....	7....
Atchison, Topeka & Santa Fe (see note)	99	97	108	120	125	106	93	105	117	130	145	119	2.0	2.2	2.6	4....	4.1	3....
Gulf, Colorado & Santa Fe	94	91	120	138	149	112	78	109	146	170	186	138	2.1	2.9	3.9	4.5	4....	3.6
Chicago, Rock Island & Pacific	46	61	69	101	130	81	51	83	81	94	119	78	1.5	2.0	2.3	3.4	4.4	2....
Chicago, Rock Island & Gulf	6	70	71	84	81	73	6	112	102	123	1....	100	0.1	2.2	2.4	2....	2....	...
Colorado & Southern	110	144	133	103	76	119	77	123	112	100	79	100	3.6	4.7	4.4	4.1	2....	3....
Denver & Rio Grande Western	123	167	134	151	137	144	126	165	129	147	145	141	4.1	5.4	4.3	4....	4.4	4....
Denver & Salt Lake	214	291	315	468	335	314	159	154	284	569	542	330	6.5	9.2	10.3	15.1	12.9	10....
Fort Worth & Denver City	1....	33	46	64	71	49	17	36	49	67	73	53	1.0	1.1	1.5	2.1	2.4	1....
Nevada Northern	117	129	132	131	140	130	83	96	108	102	112	100	4.1	4.5	4.6	4....	4....	4....
Northwestern Pacific	7....	131	73	94	128	95	37	73	44	43	99	59	2.8	4.6	2....	2.2	4....	3....
Southern Pacific Co.- Pac.Lines	57	65	62	76	92	71	50	66	67	91	107	77	1.9	2.4	2.1	2....	3.1	...
Toledo, Peoria & Western	212	256	230	278	399	275	210	309	298	372	506	351	6.7	8.1	7.2	9....	12....	...
Union Pacific (see note)	139	126	139	159	178	138	121	154	155	16....	16....	150	3.2	4.5	4.9	5.6	6....	4.3
Utah Ry.	94	166	272	259	155	189	118	194	415	403	228	272	3.6	6.4	10.9	1....	5.6	7....
Western Pacific	217	274	295	301	393	320	163	172	192	257	361	225	9.5	9.4	10.1	12....	13.2	1....
SOUTHWESTERN REGION:																		
Burlington-Rock Island	27	56	54	76	69	56	17	38	41	59	41	39	0.9	1.8	1.7	2.4	2.2	1....
Gulf Coast Lines:																		
Beaumont, Sour Lake & Western	76	110	92	77	110	93	83	109	86	83	122	97	2.5	3.7	3.1	2....	3....	3.1
New Orleans, Texas & Mexico	113	104	107	119	175	124	124	105	102	124	190	129	3.7	3.4	3....	3.9	5.7	4.0
St.Louis, Brownsville & Mexico	0	45	66	81	113	67	30	41	58	82	120	66	1.0	1.5	2.2	2.7	3.7	2.2
San Antonio, Uvalde & Gulf	4	77	76	84	122	76	108	76	70	110	142	100	3.3	2.7	2.3	3.1	3.5	3.3
International-Great Northern	113	112	115	106	101	111	112	96	101	103	102	103	4.1	3.7	3.9	3.5	3.4	3....
Kansas City Southern (see note)	111	109	102	117	132	116	122	99	101	121	137	116	3.8	3.4	3.2	3.7	4.2	3.7
Kansas, Oklahoma & Gulf	137	208	240	233	205	205	133	193	237	245	206	203	4.3	6.5	7.0	7.0	6.0	6....
Louisiana & Arkansas	254	231	230	215	197	229	267	157	137	145	143	130	8.0	7.9	7.3	6....	5....	7....
Louisiana, Arkansas & Texas	416	354	426	455	304	391	163	164	220	297	197	208	13.0	11.7	13.5	15.0	10.1	12.0
Midland Valley	64	97	80	11....	112	101	98	98	86	120	119	104	2.9	3.0	2.7	3.8	3.6	3.2
Missouri & Arkansas	228	327	227	405	430	321	90	154	100	161	191	139	7.0	10.5	7.5	13.0	13.8	10....
Missouri-Kansas-Texas Lines	99	127	125	110	124	117	108	138	127	107	116	119	3.1	4.0	4....	3.5	3.9	3.7
Missouri Pacific	184	169	218	214	195	192	142	150	193	204	212	180	5.5	5.4	7.0	6.9	6....	6....
Oklahoma City-Ada-Atoka	42	118	127	211	233	146	29	82	79	136	123	90	1.3	3.8	4.1	7.0	7.8	4.5
St.Louis-San Francisco	204	202	215	199	208	205	19....	198	220	206	209	204	6.5	6.4	6....	6....	6.5	6....
St.Louis, San Francisco & Texas	278	427	380	266	169	303	229	395	383	282	142	280	8.0	13.5	12.0	8.4	5....	9.0
St.Louis Southwestern Lines	57	72	68	179	190	113	67	86	77	184	205	124	1.8	2.3	2.1	5.7	6.0	3.6
Texas & New Orleans	87	121	66	122	132	106	77	85	49	100	122	87	3.2	4.5	2.4	4.5	4.8	3.9
Texas & Pacific	69	78	88	105	88	86	66	64	74	95	86	77	2.4	2.7	3.0	3.5	3.0	2.9
Texas Mexican	124	152	197	241	266	196	123	161	202	256	306	210	4.3	5.3	6.8	8.4	9.2	6.8
CANADIAN ROADS:																		
Canadian National (see note)	164	198	221	242	213	208	138	1.8	180	199	174	174	5.7	6.9	7.7	8.5	7.1	7.2
Canadian Pacific (see note)	104	166	161	160	161	162	104	135	135	142	143	124	5.6	5.9	5.7	5.7	5.6	5.7
Temiskaming & Northern Ontario	216	245	228	209	207	221	154	170	156	152	170	1....	7.5	8.6	8.0	7.4	7.0	7.7

Note: Statement applies to Class I roads and includes consolidated data for Class I roads merged during the period 1933 to 1937, as follows.
Gulf, Mobile & Northern - includes New Orleans Great Northern.
Atchison, Topeka & Santa Fe - includes Panhandle & Santa Fe; Gulf, Colorado & Santa Fe, and Fort Worth & Rio Grande.
Kansas City Southern - includes Texarkana & Fort Smith.
Union Pacific - includes Los Angeles & Salt Lake; Oregon-Washington R.R.& Nav.Co.; Oregon Short Line; and St.Joseph & Grand Island.
Canadian National Rys. - includes lines in New England; Grand Trunk Western; and Duluth, Winnipeg & Pacific.
Canadian Pacific - includes all lines.

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(c) Supports the rails in position both vertically and horizontally (line and surface);

(d) Provides the ballast contact necessary to retard or prevent rail creeping.

(a) Holding Gage

Function (a) need not be considered when length is determined, because other functions require greater length of tie.

(b) Distribution of Load

The loaded tie may be considered as consisting of two connected beams, each one loaded by its rail and supported by a more or less yielding ballast. The amount these beams will bend depends not only on the tie cross section and beam strength, but also on the load from the rail and on the character of the support. Ties laid on solid rock would bend very little; those on soft roadbed would bend to a much greater extent. The elasticity and resilience of the support are important, and of course quite variable.

It is well recognized that a load to be carried on a foundation, which in turn rests upon a yielding support (earth, clay, etc.), should be centered upon the foundation; that is, the foundation should project equally on each side of the load. If the foundation is not so centered with respect to the load, the tendency will be for the foundation to be pushed into the supporting earth more on the side having the least support, i.e., the foundation will tilt.

With standard-gage track and heavy rail, the center-to-center rail distance is just about five feet. Each of the two tie beams, therefore, extends toward the track center two and one-half feet and should, in order to have the rail at its center, extend outward an equal distance. Thus, to have as much tie outside as inside of each rail would require ties ten feet long.

It is because ties are not long enough to satisfy this requirement of balance that the expedient has to be adopted of not tamping them at the center of the track. The untamped portion of the tie (and also the ballast under it) is thus wasted as far as this function of the tie is concerned. Unless the centers are left untamped, there is a tendency for the track to become "centerbound", which merely means that the ties depress farther into the ballast toward their ends than they do at the center of the track.

The ten-foot length suggested above as ideal for this function neglects two facts. The two tie beams are connected at the track center and the support from the ballast cannot be made to extend all the way to the ends of the tie. The Committee on Stresses in Track has shown that the ties do not develop full ballast support for several inches at their ends. These considerations point to a length greater than ten feet as being necessary to fully give the desired balance. However, even ten feet is longer than could be justified when cost is taken into account.

An important consideration, when increased tie lengths are being weighed, is the fact that any increase in length of tie permits an equal decrease in the untamped portion of the center of the track. Thus an increase in tie length of six inches results in a decrease of one foot in length of the part of the tie which cannot be tamped.

The increase of three inches at each end of the tie permits tamping three inches farther towards the center of the track from each rail. If eight-foot ties are tamped as far inside the rail as the ends extend outside the rail (1½ ft.), the total tamped length is thus 6 ft. of the 8 ft. of tie. Increasing the length to 8½ ft. adds one foot, or 17 percent, to the support. Stated otherwise, a given depth of ballast will carry about 17 percent more load with 8½-ft. ties than with 8-ft. ties.

(c) Holding Line and Surface

Except as this function is related to that of distributing the load (b), it is not primarily affected by tie length. A tie long enough to distribute the load will, as shown by experience, be long enough to hold line and surface.

(d) Prevent Rail Creeping

The greater the length of tie, the greater the resistance set up by the ballast in contact with a tie against which rail anchors bear and transmit the force due to rail creeping. While it is true that the longer ties afford greater resistance against the creep of the rail, it is thought that ties long enough to distribute the load over the ballast properly (function b) will be long enough to hold against rail creeping.

Cost of Longer Ties

Where tie lengths have become standardized in a given production area, it usually costs more to secure a non-standard length, even if this length is less than the standard. But the added cost of longer ties, where a change in standard for the production area can be made by all or most of the purchasers in that area, is less than might be assumed on first thought.

It is only infrequently that a tree will not make as many 8½-ft. ties as 8-ft. ties. Costs of manufacturing, inspecting, unloading and inserting in track are largely unaffected by an increase of 6 in. in length. The quantity of preservative retained will be less than the amount proportional to the increase in length, because the ends retain more preservative than the balance of the tie (per unit of length), and the longer tie has no more ends.

Studies indicate that the increased cost of 8½-ft. ties over 8-ft. ties may vary from 0 to 5 percent of the total cost in track. It is thus apparent that changing from 8-ft. to 8½-ft. ties secures an increase in support of about 17 percent at an increased cost of not over 5 percent.

Conclusions

It is concluded from the above that an increase in supporting power of the roadway may be obtained by an increase in length of ties at less expense than by other means.

It is concluded that, considering the additional tie cost, 8½-ft. ties are a better buy than 8-ft. ties and will give added support out of proportion to the added tie cost.

This report is submitted as information with the recommendation that the subject be continued.

REPORT ON STRESSES IN RAILROAD TRACK

An Address by Dr. A. N. Talbot

Chairman of the Committee on Stresses in Railroad Track
Professor Emeritus, University of Illinois

This address, presented at the convention on March 15, 1939, supplements the report of the Committee on Stresses in Railroad Track appearing on page 625 of Bulletin 409 and of the Proceedings for 1939.

Service Tests of Various Types of Joint Bars

The Stresses in Track investigation is continuing its co-operation with the Committee on Rail in observational tests on the rail joints in the 12 half-mile stretches of track on the Pennsylvania Railroad and the 9 one-mile stretches on the Atchison, Topeka & Santa Fe Railway. The report of Subcommittee 8 on Service Tests of Various Types of Joint Bars presented by Mr. Faries (see Appendix J of the report of the Committee on Rail, beginning on page 621) gives information on the progress of the tests. Members of the staff of the Committee on Stresses in Railroad Track act as observer and recorder of the conditions prevailing on the test stretches laid with the various types of joint bars and endeavor to record facts bearing on the life history of the rail joints over a period of years, as stated in the report of Subcommittee 8. During the year various observational tests have been made as follows: Rail surface middle ordinate in 34½ in., vertical mid-ordinate and lateral mid-ordinate of joint bars, profile of the rail at the joint, profile of the fishing surface of the bar, rail batter, fit of bar, bolt tension, out-to-out distance of bars at three points in the length, and the joint gap, besides observations on the appearance of wear and something on variations in fishing heights.

These various tests and measurements are expected to give pertinent information in regard to wear and its sources, the changes that occur in the parts of the joints, the care and needs in maintenance, and the characteristics of deterioration and the requirements of joint maintenance—all for the various types of joint bars. Most observational measurements provide data that will be useful in later years as wear and other changes develop. Comment may be made on a few matters of current interest.

It is thought that information on the magnitude of the bolt tension put into the joints and its decreases under time and traffic, its action on retightening, and the general effects of low, moderate, and high tension in the bolts is greatly needed as bearing on the life and the maintenance of joints; and attention is being given by measuring the bolt tension on a limited number of joints at different times, especially just before retightening and afterward, and still later. Unfortunately the measurements of tension in a bolt consume more time than most of the other measurements made, and so far only 6 to 12 joints in each of the 21 test sections have had the bolt tension periodically measured. However, these measurements give information of interest.

In Fig. 1 are plotted the average observed values of the bolt tension on each of the nine test sections of the Santa Fe. The bolt tension first measured in November, 1937, three or four months after the final surfacing and retightening of the bolts, is represented by the rectangles having diagonal hatching, namely, the first ones in each group. It will be seen that these early averages of bolt tension ranged from 5,000 to 15,000 lb. The solid, black rectangles represent the tension measured in February, 1938, and in general show a slight dropping off in the tension. Immediately after these readings were taken, the bolts were retightened, the tension being increased materially, as shown by the open rectangles. The existing tension was again measured in July, 1938, shown by the lined rectangles; it will be seen that over this five month period the drop in

tension ranged from 5,000 to 8,000 lb.—an average loss of 37 percent. In October, 1938, the tension was again measured on three sections (Miles 100–101, 101–102, 102–103), represented by rectangles with cross lines; the loss in tension averages about 36 percent.

It is apparent that the first measured tension (that measured three or four months after the final retightening after track laying) was fairly permanent, with little loss through wear of bars and adjustment into place. In the February tightening (made without loosening the bars from the rail) the intent was evidently to increase the tension considerably, but the higher tension did not hold well, and it continued to decrease as shown by the October observations on the three sections measured. It may be well to add that the washers used in these joints give little travel for bolt tensions beyond a few thousand pounds. Attention may be called, also, to the fact that the spring of bars at bolt tensions above 8,000 or 10,000 lb., and especially above 15,000 lb., produce little spring or lateral travel of the bar and thus the higher tensions are easily lost. There is a further question, too, on the effect of high tension on bearing and other stresses in the bars and hence upon their durability strength.

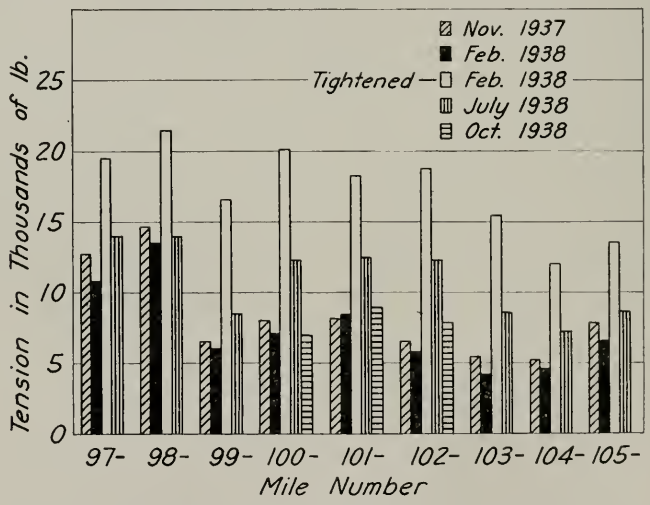

Fig. 1. Average Bolt Tension on Each of the Nine Test Sections of the A.T. & S.F. Ry.

In the joints on the Pennsylvania Railroad the measurement of tension showed that these bolts averaged about one-third less tension in October, 1938, than in November 1937—with no tightening of the bolts in the interval between these measurements. A loss of this kind is to be expected because of some wear of the bar and rail and because the bar and rail have been pulled closer together through the action of traffic. The average tension per bolt in the several sections in October, 1938, ranged from 7,000 to 12,000 lb. (with 27,000 lb. on one type of bar). Later measurements showed that some joints had less than 5,000 lb. in one or more bolts. A few joints showed even lower tension. Notwithstanding the tension in the bolts of many of the joints may be called moderate or even low, the condition of these joints remains satisfactory.

The measurements of changes in length of rail gap due to changes in temperature between summer and winter will be useful in learning the variations in movements of rail ends at the joints and in holding or "freezing" for the different types of joint bars

and different bolt conditions, as bearing on variations in the wear and life of the joints as time goes on. In Fig. 2 is shown the number of joints developing decreases in gap from 0 to 0.35 in. between a rail temperature of about 35 deg. F. in February, 1938, and one of about 115 deg. F. in August, 1938, (80 deg. change in temperature) for two sections of the Santa Fe—the number of joints with a given gap being stated in percentages of the whole number in the mile, and the changes in gap being grouped to the nearest 0.05 in. The mile shown in the upper diagram has 36-in. bars and that in the lower diagram 24-in. bars. It will be seen that on both sections the groupings range from a small percent at no movement (2 or 3 percent) upward to 22 or 25 percent at changes near the average and then drop sharply downward to a small percent at a change of gap of 0.35 in. The distribution of the changes in gap in these sections may be said to approach the ideal practicable—few frozen joints and few of large gap, with most of the movements lying near the average. The average change per joint for the upper diagram is 0.16 in. and for the lower 0.19 in. These average changes in gap correspond to 0.68 and 0.82 of the calculated unrestricted temperature expansion of rail steel over the temperature change for the two sections, respectively. It may be

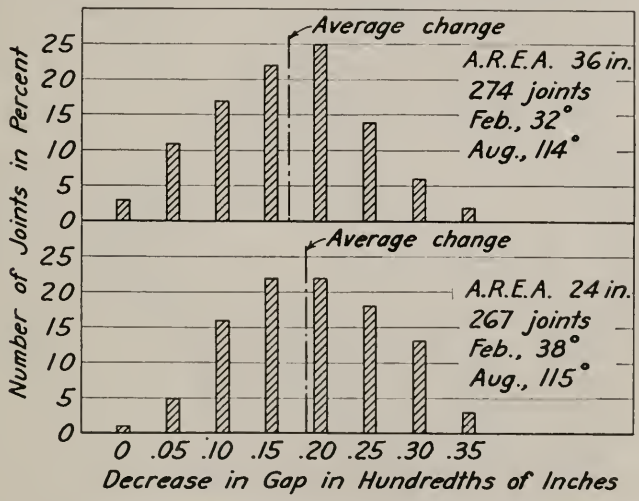

Fig. 2. Changes in Rail Gap on Two Test Sections of the A.T. & S.F. Ry.

noted that the average bolt tension for the joints measured in the upper diagram was 19,000 lb. at the winter gap readings and 12,000 lb. at the summer gap readings, and the corresponding average bolt tensions in the lower diagram were 15,000 and 8,000 lb. The higher ratio of movement to calculated expansion in the latter section could be due partly to the lower bolt tension and partly to the presence of four bolts instead of six.

In Fig. 3 are shown similar percentages for two half-mile sections on the Pennsylvania Railroad. In the upper diagram the distribution of gap for the 24-in. AREA joint bar is quite similar to that found in Fig. 2. The average change in gap is 0.18 in., which for a 75-deg. change in temperature corresponds to 0.80 of the full contraction of rail. The measurement of bolt tension averaged 11,000 lb. one month after the summer gap readings were taken and three months before the winter gap readings.

The joints of the lower diagram have 36-in. head-free bars. The values indicate a greater restraint and a larger proportion of joints with no change or relatively little gap change than are shown in the upper diagram. The average change in gap of 0.11 in. represents 0.44 of calculated unrestricted contraction for the 83-deg. change in temperature. Doubtless the higher restraint is largely due to the high bolt tension which, for the joints measured one month after the summer gap measurements, averaged 27,000 lb., while the tension measured for joints in the upper diagram averaged 11,000 lb.

For the test stretches on both railroads, it should be noted that the rail gaps were not measured at extremes of temperature, and doubtless greater variations existed at such temperature, together with increases in the temperature stresses developed in the rails at minimum temperatures at various places, as aggravated by the limiting positions in the punchings of the bars, especially as the gaps existing at the higher temperatures were larger than expected.

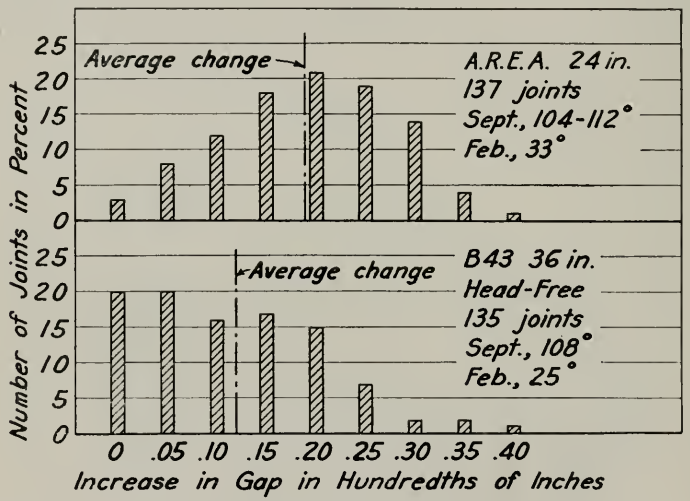

FIG. 3. Changes in Rail Gap on Two Test Sections of the Pennsylvania Railroad.

Notes of general observations made on the joints, such as the appearance of wear at the joint, both as compared with it away from the joint and the contrast between end hardening and rail treatment on the south line of rail and ordinary rail on the north line, are showing interesting developments, but these and other observations are not yet conclusive. The effort is being made to increase the distance in each section on which systematic observations are made. Not all kinds of observations will be made annually. The newer instruments and more of the progress of the tests are referred to in the report of Subcommittee 8.

Observations on Welded Track

The observations on the several stretches of continuously welded rail have now covered a period of three years on the Delaware & Hudson Railroad and two years on the Bessemer & Lake Erie Railroad. The measurements have consisted mostly of strains in the rail and the corresponding temperature of the rail for the ranges of temperatures found in the winter and summer seasons. In some cases the movement of the rail

with reference to fixed points outside the track has been measured by the railroad company. Since the readings of the last year have been closely in accord with results previously reported they will not be given in detail.

The service on part of the test track having covered a period of three years, it will be well to compare some of the results for the whole period to find how stable and consistent the action of the track has been. Fig. 4 represents the temperature stresses in the two rails measured over the three-year period at five points near the south end of a test stretch on the Delaware & Hudson Railroad. The points are situated from 10 ft. from the end back to 370 ft. from the end. The readings are the results of the summer and winter tests of 1936, 1937 and 1938, and are designated on the diagram according to the legend at the right side of the figure. The temperature stresses are plotted as abscissas, tension stresses being positive and to the right of the

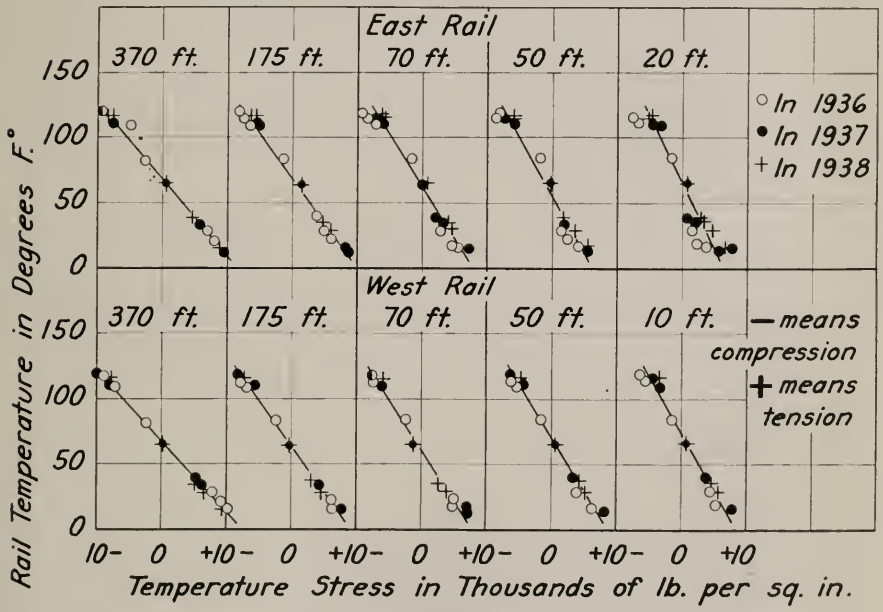

Fig. 4. Temperature Stresses in Rail Near One End of a Welded Stretch—Delaware & Hudson.

individual vertical axes, and compression stresses negative and to the left. The ordinates are the measured temperatures of the rails for the summer and winter tests. In many cases all the points could not be plotted to the scale of this diagram because of the close similarity of the results. The reference temperature for the stresses is 73 deg. F. and is based on a set of readings taken in the summer of 1936. The first set of readings taken in the summer of 1935 is omitted because of the large adjustment in rail length that occurred in cold weather, when the south end of the track pulled out. This breakage was attributed to a high laying temperature, an undesirable practice. The track adjoining this stretch is another welded stretch over a mile in length.

It will be noted that at all five locations on both rails there is a straight-line relation between rail temperatures and temperature stress. This straight-line relation indicates that along the anchorage portion of the test stretch the temperature stress in rail at any

place is always closely proportional to the change in temperature. Thus the length of track giving anchorage remains the same throughout the range of temperature under both tensile and compressive forces, and the anchorage force given by a tie is proportional to the temperature and has not a constant value as has been assumed in some analyses. These relations hold for the six sets of observations made in summer and winter of the three consecutive years.

The magnitude of the temperature stresses increases gradually from the end of the stretch to the fixed portion. The stresses amount to about 6,000 lb. per sq. in. at the end of the stretch and increase to about 10,000 lb. per sq. in. at 370 ft. from the end. The development of the stress of 6,000 lb. per sq. in., shown at 10 ft. and 20 ft. from the end, requires a pull or push through the joint from the adjoining stretch of about 75,000 lb. for each rail for a 50-deg. F. increase or decrease from the base temperature. The uniform relation between temperature and stress in rail at all these places for the six sets of observations and the condition of the track at higher and

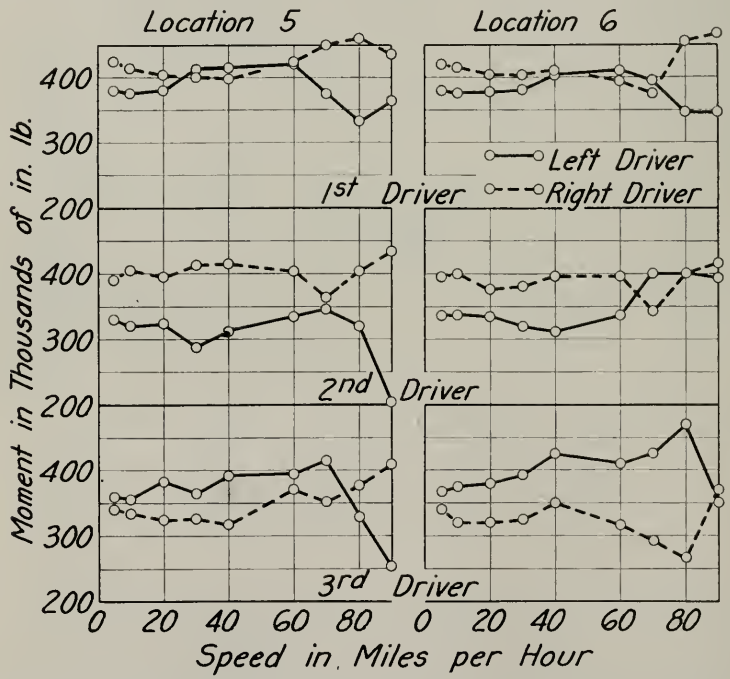

Fig. 5. Moments in Each Rail under the Drivers of Pennsylvania Electric Locomotive 4779.

lower temperatures show that the same relations of stress and position of track have been sustained even for extremes of temperatures beyond the plotted range covered by the observations. The close grouping of the points shows that this track (which is considered representative) has been stable and consistent in its behavior during the three-year period.

Some portions of the test stretches have been subject to local variations, the effect of which was apparent in the observations. Replacement of a couple of welds allowed the track to readjust itself, as was also the case when some of the track was given a

lift and surfacing. One stretch laid at a high rail temperature pulled out at one end during cold weather and was loosened for adjustment at the other. These local variations sometimes obscured the action of the track for temperature changes. It is judged important to lay the track at a median or moderate rail temperature to equalize the tensile and compressive forces.

No attempt has been made in the observations to examine and determine the quality of the welds and their permanency. It seems probable that recent developmental work on welding processes and the systematic testing of the welds in the investigation of the Committee on Rail will result in improvement in the quality of the weld. The installation of additional stretches of rail welded under improved processes will help to furnish needed information on the life and permanency of this type of construction.

Moments in Rail and Rail Joints

The tests of rail joints and track on the Pennsylvania Railroad, the equipment used and the readings taken were described in considerable detail before the convention last year. This description may be found on page 857 of Volume 39 of the Proceedings.

The study of the effect of speed and other conditions on stresses in rail and in joint bars was rendered difficult by variations in the action of the locomotive, especially at the higher speeds. This was the case even though the locomotive used for loading the joints was an electric locomotive with no unbalanced rotating or reciprocating forces. Something of the variation found with the locomotive is shown in Fig. 5. This figure gives the moments obtained from the measured stresses in the base of the rail from four of the six strain gages used and for the three driving wheels of the locomotive. The values plotted for each location are from a pair of strain gages directly opposite each other on the two rails. The moments are plotted vertically and the speed in miles per hour horizontally. The results for the first driving wheel are at the top, the second just below it, and the third at the bottom. Values for the right rail are plotted as the broken line and for the left rail as the full line. It should be noted that zero axes are not shown on the diagram. Most of the plotted points are the average of several runs at the given speed.

A principal matter of interest in this diagram is the relation of the bending moments in the right and left rails for driving wheels on the same axle. It is seen in practically all cases that at a given speed a variation of bending moment in one direction on one rail is matched by an approximately equal and opposite change in magnitude in the other rail. The summation or average of the two rails for the first second, or third driver would give an almost exactly horizontal line, indicating a net speed effect for the two sides of negligible amount. The locomotive would appear to be rocking from side to side or perhaps oscillating longitudinally about a vertical axis, with lateral pressures against the rails, and the rocking or oscillation is at different phases on passing an instrument at the various speeds. The data illustrate some of the variations in the action of a locomotive found in field tests even under optimum conditions.

For example, for the second driving wheel on Location 5 (middle diagram on left side), the right driving wheel (dotted line) develops in the rail a bending moment of 400,000 in.-lb. (equivalent to 14,600 lb. per sq. in. stress in the base of rail) for speeds up to 60 m.p.h., with some variation from that magnitude at 70 and 90 m.p.h. At the same time, the left second driving wheel (full line) develops an average moment in rail of about 320 000 in.-lb. (equivalent to 11,700 lb. per sq. in. stress in base of rail) except at 90 m.p.h. where it is only 200,000 in.-lb. And yet the average for the two driving wheels does not differ far from 360,000 in.-lb. over the whole range of speed.

It is apparent that conditions have made a transfer of load from one wheel to another on the same axle.

As a result of some of the variations illustrated and certain other uncontrollable variations, the rail-joint tests in the field have in some respects been indeterminate and inconclusive in regard to the effect of some of the factors in the tests. For this reason and because of the quantity of data involved, no attempts will be made in this discussion to give the details of the results.

Stresses and relative movements were measured in various types and sections of joint bars under various conditions for speeds up to 90 m.p.h. Joints were tested with the joint bars used as found, with bars ground to straight true surfaces ("machine fit"), ground to simulate a worn condition, and as found after considerable service in track. Some joints were tested to compare bars with controlled bearing and full

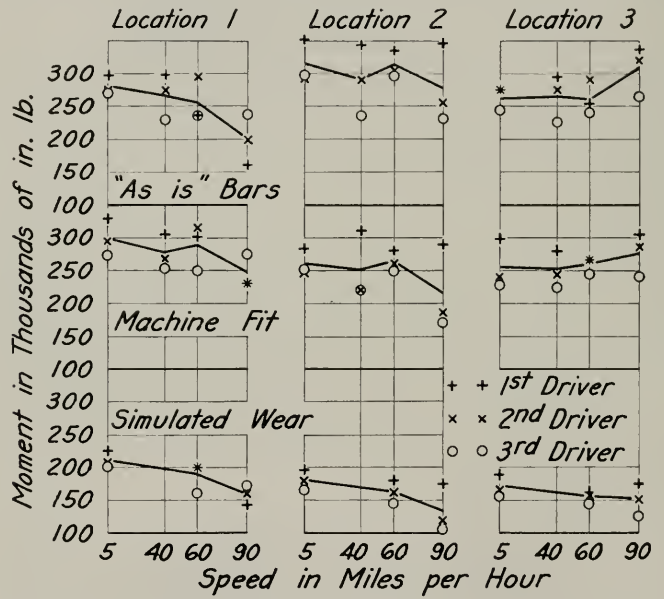

Fig. 6. Moments in Rail-Joints with Three Conditions of Bars —Pennsylvania Tests.

bearing. Long bars and short bars were also tested under conditions otherwise comparable. It was found in these tests that the variables present in the track and the locomotive to some extent obscured or counteracted the effect of the variations in the type of bar or its conditions. Certain variable factors in the bars themselves unrelated to the subject of the test caused variations of sufficient magnitude to be of primary importance. One of these factors was camber of the rail joint which has been found to be determined by the camber or condition of the bars.

Bending moments found from the measured stresses in a representative group of the rail-joint tests are given in Fig. 6. The joint bars in all cases are a moderate-weight symmetrical section for 131-lb. rail, and three joints were tested at three locations for each test condition. Two test joints in Location 1 and Location 3 were on the right rail and were consecutive; that on Location 2 was on the left rail midway between the other two. Two ordinates of the diagram represent the vertical bending moments at

mid-length in the joint bars and are plotted with reference to the speed of the locomotive as abscissas. The results for the three conditions of joint bars ("as is" bars, machine fit and simulated wear) are given from left to right under the headings Location 1, Location 2 and Location 3. The average values for individual driving wheels are plotted according to the legend shown. A line is drawn between points representing the average for the three driving wheels at each of the several speeds.

Inspection of this figure shows a wide spread of values for the several driving wheels at the higher speeds in somewhat the same manner as illustrated in tests of rail in Fig. 5. The grouping of the points at five miles per hour is generally much closer than at the higher speeds, and the relative position of the points is often reversed at the higher speeds from that at five miles per hour. It may be stated here that the weighed loads for the driving wheels on the right side of the locomotive were appreciably greater than on the left side.

It may be expected that the driving wheels of this locomotive will develop a bending moment in the rail of 350,000 to 400,000 in.-lb. The effectiveness of a rail joint may be said to depend upon the closeness to which the moment developed approaches to that of a full rail, though it is not to be expected that the values for the joint will reach those of the full rail. An ineffective joint will develop a lesser bending moment than that given by a rail; in other words, a joint that develops materially smaller bending moment (and has a smaller stiffness) is not doing its work properly. In the figure, the values for the bending moments (recalling that the weights applied on the two rails may not be the same at the high speeds) are fairly high for the "as is" joint bars and for the "machine fit" bars, while those for the "simulated wear" are materially lower, being in some cases as low as 150,000 in.-lb.

The trend of the moment values as the speed increases is seen to be variable and in some cases even downward, indicating lesser stresses. This trend is felt to be primarily a result of oscillation or rocking of the locomotive or lateral pressures applied by the wheels in a particular manner at a certain location rather than an actual improvement of the stress values for higher speed. These variations make evident the difficulty of isolating the effect of any test condition unless the effect is of large magnitude.

As the analyses and interpretations of the tests on the Pennsylvania Railroad have made good progress it is planned to make a full report soon.

The Rolling-Load Testing Machine

Fig. 7 is a view of the new rolling-load rail-joint testing machine, which was put into continuous operation in October, 1938. The purpose of this testing machine is to make laboratory studies of long-time tests of rail joints—forms of joint bars, manner of failure, wear of bar and rail fishing surfaces and sources of such wear, effect of repetitive loading, life of joint bars under repetitive loading given by locomotive wheels and heavy cars and lighter wheel loads with the number of applications causing failure for the various wheel loads used, and possibly the determination of endurance limit loads for bars of different form and different materials.

The stroke or travel in this rolling load testing machine is 33 in. As now operated, the wheel giving the load in rolling from a point 6 in. to the left of the middle of the 36-in. span on to the right support applies a positive moment (downward deflection) and then in passing on over the overhanging cantilever portion for a distance of 9 in. produces a negative moment (upward deflection) in the part between the supports, and the maximum negative moment applied at the center of the joint is one-half of the maximum positive moment developed at the same point. A load of 44,400 lb. produces a positive bending moment of 400,000 in.-lb. (the moment that was used as a criterion

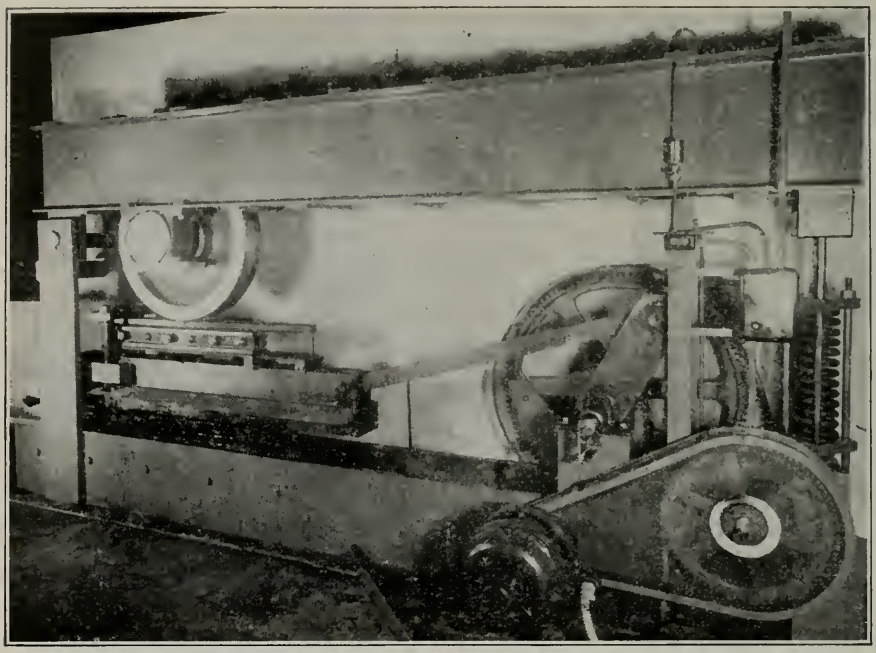

FIG. 7. View of 33-in. Stroke Rolling-Load Testing Machine.

in the calculations and design of joint bars in the Sixth Progress Report) and a maximum negative moment of 200,000 in.-lb. The testing machine was designed to develop a maximum positive moment of 600,000 in.-lb. or more. Adjustments easily made permit application of any moment below this limiting value. The 36-in. span used gives a form of positive moment curve that approximates that produced in a rail by a group of wheel loads.

Fig. 8 is a sketch of the working arrangement of this rolling load machine for testing rail joints. The rail joint A rests on supports B and C, spaced 36 in. apart. Actuated by the motor, the rail-joint and table D roll back and forth from E to F as the wheel W is rotated. When the wheel is between E and the support C positive bending moment is applied to the joint. When the wheel is over F at the end of the cantilever a negative bending moment is applied to the middle of the joint equal to one-half of the maximum positive bending moment. With the wheel on the cantilever part, the rail is held down at the support B. The connection between the base and the loading has been cut away in the sketch. The applied wheel load is produced by compression of the spring S acting on the I-beams carrying the wheel with a 5-to-1 lever ratio, together with the weight of the wheel and other parts. The machine operates at 27 cycles per minute, 39,000 cycles per day. It seemed impracticable to operate the machine much above this speed due to the high acceleration and deceleration forces caused by the long stroke and heavy table.

The first rail joint to be put in the machine contained AREA 36-in. heat-treated bars with 112-lb. rail. The initial bolt tension was set at 15,000 lb. per bolt. A positive bending moment of 400,000 in.-lb. and a companion negative moment of 200,000 in.-lb.

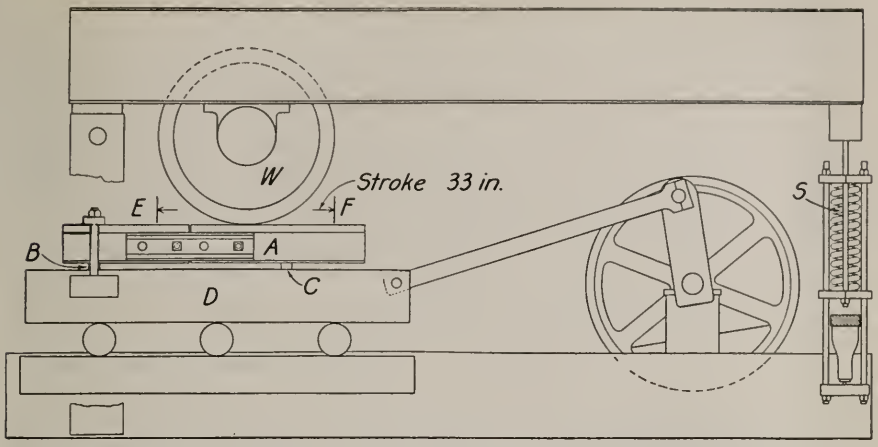

FIG. 8. Diagrammatic Sketch of Rolling-Load Testing Machine.

was applied each cycle. The calculated stress in the bars (not considering any initial clamping stresses) was about 40,000 lb. per sq. in. The joint failed at 634,000 cycles, equivalent to an application of 14,000,000 tons by this wheel load of 44,400 lb. The failure occurred by a fatigue crack starting at the base of one of the bars a little inside of the middle of the lower bearing surface back about 1/3 in. from the rail end, a definite fatigue failure from tensile stress at the bottom of the bar. In Test 2 a similar rail joint was tested with the same wheel load as used in Test 1; it failed at 479,000 cycles, equivalent to an application of 10,500,000 tons of the wheel load. This time the crack in the bar started back two inches from the rail end and progressed up from the base of the bar into the inner bolt hole, also a definite fatigue break at the bottom of the bar. The type of failure in the two joints was in all ways similar. Measured longitudinal stresses near the base of the bars of Test 2 were approximately 43,000 lb. per sq. in. tension under the bending of 400,000 in.-lb., of which about 13,000 lb. per sq. in. was initial stress due to tightening the bolts. It was not possible to determine the additional strains produced by high concentration of bearing pressure between rail and bar (clamping action).

As it was thought that loads and moments as high as or higher than those used in the two tests are not infrequently applied to joints in track having heavy traffic, the failure at tonnages named with this load of 44,400 lb. was something of a surprise.

In Test 3 a smaller load was used, 35,500 lb., giving a positive bending moment of 320,000 in.-lb. and a negative moment of 160,000 in.-lb.—a 20 percent reduction. As before, a bolt tension of 15,000 lb. was used. With the 35,500-lb. load the calculated stress in the bars was 32,000 lb. per sq. in. Before starting the test, the measured maximum stresses near the base of the bar under a load were 29,000 to 32,000 lb. per sq. in., of which 5,000 to 8,000 lb. per sq. in. was present as initial stress. At 1,000,000 cycles, the measured stresses were 22,000 to 25,000 lb. per sq. in. of which in one case the initial stress had become 6,000 lb. per sq. in. compression. It should be added that the measured stress in the top of the bars for both Tests 2 and 3 under the load was numerically higher than that in the base. The joint failed at 1,501,000 cycles, equivalent to the application of 26,600,000 tons by the wheel load. The failure was similar to

that of Test 2, a fatigue crack starting at the base about 1½ in. from end of rail and progressing upward into a bolt hole.

Test 4, involved the use of 24-in. bars in which a sizable fatigue crack had developed at the top fishing surface of the bars near the rail ends under traffic in the track of the Denver & Rio Grande Western Railway. This joint failed at 168 000 cycles (equivalent to the application of 3,700,000 tons by the wheel load of 44,400 lb.) by the extension of the fatigue crack in one of the bars vertically downward from the top. The large number of cycles applied in the testing machine upon removal from track is indicative of continued resistance to fracture after the bars have become cracked in track.

Bars from service and bars made under controlled conditions are also now available for test.

In connection with the tests with the rolling-load testing machine, sets of systematic measurements are taken at appropriate intervals. Some of these may be named,—profile of rail surface, profile of the bar fishing surfaces and the companion rail fishing surfaces, bolt tension and its changes with time, stresses in the top and bottom of the bars due to bolt tension clamping effects and wear, as well as to the applied loads. The tests have brought out the definite need of information on the nature and variation of the material and its ability to withstand the various demands made upon it.

Remarks on Properties and Failures of Joint Bars

Failure of joint bars in a laboratory rolling-load test at loads and stresses and cycles of loading which may seem somewhat smaller than some may have surmised for heat-treated carbon steel joint bars raises questions on the quality of materials, endurance limit, cycles of loading to produce failure at stresses higher than the endurance limit, manner of failure under repetitive loading, injurious effects of high bearing pressures produced by bolt tension (clamping effects) and load, effect of the softer decarburized metal at the surface of the bar and of its surface roughness. Besides, does the material in the bars of the joints tested meet the best requirements available for the purpose (presumably they filled the requirements for standard specifications), or is it possible to produce bars better fitted for the purpose? What is the situation with respect to the quality of joint bars?

Specimens cut from the bars gave an ultimate tensile strength of from 95,000 to 123,000 lb. per sq. in. and a yield point from 48,000 to 76,000 lb. per sq. in. It is judged from the hardness tests that one bar in Test 2 has a tensile strength even lower than the minimum value given above. Hardness along the length of the bar and across the section varied considerably, ranging from 175 to 240 in Brinell hardness, and down to 140 in one bar, and the bars were harder near the ends than at the middle. In Test 3, the load of 35,500 lb. gave a measured stress in the bars of 32,000 lb. per sq. in., which may not include the localized stress at points where the bearing pressure is large. It is to be expected that the actual stress at such points was somewhat greater than the endurance limit of the material at the point of fracture. The endurance limit of joint bar steel for complete reversal of stress probably may be expected to range between 45,000 and 60,000 lb. per sq. in. As in the testing machine the negative moment is only half of the positive, the stress causing fracture (endurance limit for the range in stress in question) would be greater than for complete reversal. Information is needed on the actual endurance limit of the material in the joint bars at the point of fracture and on the maximum stresses developed in the bars at points of concentration of pressure. It should not be forgotten that the bars used in these tests may not be representative.

In a discussion on the strength of rail joints, it must be understood that because of variation in wheel loads to values above the nominal loads and by reason of imperfect

supports and of imperfect bars and high initial stresses in the joint, intensified by unnecessarily high wrenching, the rail joint in track does receive with considerable frequency the equivalent of far higher loads than the loads nominally talked about. In designing joints allowance should of course be made for these heavier values which will be developed in track.

On the other hand, however, for failures by repetitive loading the matter of the number of repetitions of a given high wheel load or of a given medium wheel load is an essential element in the problem of determining the design load. To speak in the terminology of fatigue of metals, in accordance with the S-N diagram (stress producing fracture in a given number of cycles or applications of load of a given kind), the breaking stress decreases markedly with an increased number of applications, but finally at the endurance limit the value of the breaking stress approaches constancy for an indefinite number of cycles—that is to say, after perhaps a million applications, more or less, for such steel as is used in joint bars.

In choosing a wheel load on which to base the design of the strength required in a joint bar to meet the needs of traffic of a given kind, the question arises, do the heavy driving wheel loads govern, or may a more frequently applied wheel load of heavily loaded freight cars influence failure to a greater degree? Also, if the still lighter wheel loads constitute a considerable proportion of the traffic, may not the total amount of these lighter loads be deducted from the annual tonnage in judging of the amount of traffic which will cause fractural failures, and may not such lighter loads even give longer resistance to fracture? For a heavy traffic road, will wheel loads of 30,000 to 40,000 lb. constitute more than a small percentage of the total annual tonnage, and will not wheel loads of 20,000 to 25,000 lb. make up a much higher percentage and by their frequency thus control the stress which may cause fracture? As a rough guess the conditions of traffic and operation might be such as to cause the heavy driving wheel loads to furnish 5 percent of the total tonnage, the medium wheel loads 20 percent, and the lighter loads 75 percent of the total tonnage. May not the high proportion of the still lighter loads add to the wear of joints and thus avoid the presence of many fractural failures? To cite another probability, may the joint by reason of its form or fit or material so shirk its duty as not to carry its proper proportion of rail stiffness and rail load and thus by reason of its lower stresses continue in service until wear of parts causes replacement, its inefficiency meantime giving all the troubles of low joints? Actually, a joint is desired that will do its job as well as possible, even at the risk of breakage.

This discussion may then suggest the need for adequate information on the fatigue properties of the metal in joint bars "as is", including the variation in different parts of the bar. Tests in small ways have been started and show need for a full investigation. A more complete study of the general physical properties is needed. The study should also go into the effect of the decarburization at the surface of the bar and of surface roughness to learn the effects on fatigue failure; also, on such matters as the nonuniformity of hardness of the material in the various parts of the bar. To aid in utilizing the knowledge of the fatigue properties of joint bars, a statistical study of the proportional value of railroad tonnage taken by heavy, medium, and lighter wheel loads should be made with some definiteness, as may be found on railroads having different types of traffic.

Tests have also been started to find the effect of the distortion of the rail head at and near the rail end seemingly often applied in the hot sawing of rails, a condition which apparently pinches or otherwise injuriously affects the life of the bar under load. Still

further tests with the rolling-load testing machine are greatly needed, but unfortunately the tests are necessarily very slow.

This informal report has already been too long. If there were adequate time some mention might well be made of experience of some western railroads with numerous instances of the formation of fine cracks (fatigue cracks) at the top of the bar and in some cases at the bottom near the rail ends for joints on 112-lb. rail and perhaps an account might be given of the studies and tests made by the Denver & Rio Grande Western Railroad to learn the source and the remedy for the fracture. Photoelastic studies and metallographic tests have been made by Mr. Ray McBrian engineer of tests of that road. Repeated load tests on unused rail joints in which an unusually heavy load is applied 40 times a minute on a span of 36 in. (compression in the top of the bar) and no negative moment is used, produce these cracks at the top of the bar in from 10,000 to 100,000 applications. Among the matters thought of as possibly contributing to the fractures in track at both the top and bottom of the bar are high bolt tension, the large concentration of stress at the principal bearing places on the bar when combined with very high bolt tension, the closing down or distortion of the head of the rail on one side done in hot sawing and the consequent pinching and concentrating of high bearing pressures on the bars, and decarburizing of the bar surface. The Stresses in Track investigation is co-operating in the attack on this problem. It should be noted in this connection that all failures with the rolling-load testing machine have been at the bottom of the bars.

FIFTH PROGRESS REPORT OF THE JOINT INVESTIGATION OF FISSURES IN RAILROAD RAILS

By H. F. Moore
Research Professor of Engineering Materials, University of Illinois
In Charge of the Investigation

I. INTRODUCTION

1. Previous Work of the Investigation:—The previous work of the investigation has been published in four progress reports submitted to the American Railway Engineering Association.*

The genesis of an internal fissure, transverse or otherwise, in a rail is nearly always, if not always, a shatter crack in the interior of the head of a rail. However, it must always be borne in mind that only a small percent of shatter cracks develop into fissures. A shattercracked rail is not devoid of strength altogether. However, it has its strength reduced, sometimes by as much as 50 percent. The search for the cause of and means of prevention of shatter cracks has been a major feature of the investigation. Rolling-load tests have shown that the spread of a fissure is started not by bending stress, but by the complex localized stress directly under a wheel. The theoretical shearing stress at the end of a shatter crack, the strength of cracked rail-steel specimens developed in fatigue tests, and the wheel load found necessary to develop fissures in shatter-cracked rail specimens tested in a repeated rolling-load testing machine,[1] – all these fit into a consistent picture of the mechanism of the development of internal fissures in rails.

An extensive study of the prevention of shatter cracks by means of controlled cooling of the rails has been made. The data of the tests made are given in the fourth progress report and in this report. Tests have been made on rails produced in the normal way and on rails produced from ingots through which hydrogen was passed during the molten state. This produces a large number of shatter cracks, and was used on the assumption that if such very serious shatter cracking could be prevented by controlled cooling, then the much smaller amount of shatter cracking found in some heats of rails produced in the normal way and cooled on the hot bed could also be prevented. It may be stated that controlled cooling in the test heats of rails studied has been successful in preventing shatter cracks in both hydrogen-treated rails and normally produced rails.

Considerable study has been made of acceptance tests for rails. Bend tests, with autographic record of load and deflection, have given more consistent results for the detection of badly shatter-cracked rails than has the standard drop test. The drop tests when used head-up did not detect shatter cracks as well as did the drop test head-down. Persistent attempts have been made and are still in progress to find some non-destructive test for shatter cracks which can be applied to newly rolled rails. So far the results, while they have given some promise, have not developed a test usable in service.

A large amount of data has been accumulated on the strength, ductility and toughness of rail steel. Test data have been made on rail steel at temperatures varying from –50 deg. F. to ordinary summer temperatures. Tests made have included tensile tests,

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* The First Progress Report appeared in the AREA Proceedings, Vol. 36, pp. 1065–1090 (1935) and in Reprint No. 4 of the Eng. Expt. Station, University of Illinois, copies of which are exhausted.
The Second Progress Report appeared in the AREA Proceedings, Vol. 37, pp. 998–1012 (1936) and in Reprint No. 8 of the Eng. Expt. Station, University of Illinois.
The Third Progress Report appeared in the AREA Proceedings, Vol. 38, pp. 645–673 (1937) and in Reprint No. 11 of the Eng. Expt. Station, University of Illinois.
The Fourth Progress Report appeared in the AREA Proceedings, Vol. 39, pp. 807–856 (1938) and in Reprint No. 12 of the Eng. Expt. Station, University of Illinois.

[1] A detailed description of the rolling-load testing machine is given in the First Progress Report.

fatigue tests (in repeated tension, repeated compression, reversed flexure and in reversed and repeated torsion), impact tests (flexure tests of notched and of unnotched bars, and impact tension tests on unnotched bars), and static bending tests of notched bars with complete autographic load-deflection diagrams. Tests have also been made on the properties of rail steel heat treated to various degrees of hardness. Perhaps the outstanding feature of these tests of rail steel has been the conclusion that with proper heat treatment it is possible to increase the strength, the ductility, the toughness, and to diminish the sensitivity of rail steel to low temperature effects.

The question of end hardening of rails has become a major factor of the investigation. Laboratory tests in a rolling-load machine have shown a very marked diminution of end-batter for end-hardened rails. In a general way hardening below about 320 Brinell does not seem to decrease the batter very much, while hardening above 450 Brinell is apt to make the steel so lacking in toughness that it chips easily. So far, the rolling-load laboratory tests have not been sufficiently sensitive to differentiate between methods of end hardening, provided that the above range of Brinell hardness is maintained.

The problem of the severity of punishment which rails receive in practice has been studied by means of field tests in which the bending strain in rails under actual service was determined by the use of a DeForest scratch extensometer. These tests are reported in the first, the second and the third progress reports. Records were obtained under some 500,000 wheel loads taken at four locations: (1) On the Baltimore & Ohio Railroad north of Dayton, Ohio, under heavy coal and ore traffic; (2) near Coatesville, Pa., on the Pennsylvania Railroad under heavy coal traffic; (3) on the New York Central Railroad near Rome, N. Y., under mixed freight traffic; (4) on the Atchison, Topeka & Santa Fe Railway near Matfield Green, Kan., under tank-car traffic and mixed freight. These results indicated in a general way that at a given location about one wheel load out of one thousand[2] might be expected to reach a value of about 40,000 lb. or higher.

The value of 40,000 lb. seems signficant in view of the fact that 40,000 lb. was the lowest wheel load which the laboratory tests in a rolling-load testing machine developed an internal fissure in a shatter-cracked test rail. In this connection it may be noted again that experiments showed that rail fissures were developed by the direct action of the wheel load rather than by the bending moment on the rail. Fissures were developed in test rails having a very small bending moment and attempts to develop fissures with repeated bending moment without the direct application of heavy wheel load at the points of maximum bending were unsuccessful.

The test party of the investigation has kept in close contact with Mr. W. C. Barnes, engineer of tests, of the AREA and his annual reports on fissure failures in service. Members of the test party have been out on detector-car tests on various occasions. It may be remarked that so far the service reports from the detector car are in harmony with the conclusion that shatter cracks are the major cause of transverse fissures, and that controlled cooling or other suitable thermal treatment is an effective means of preventing shatter cracks.

Extensive metallographic studies and a considerable number of chemical analyses have been made in connection with the study of rail steel and of end-hardened and fractured rails. These studies have thrown light on the structure of steel, and have shown that rail steel is very nearly pure pearlite with occasional traces of ferrite in rails with the lower carbon range, and of cementite in the rails with higher carbon range. The studies

[2] Special experiments in the Talbot laboratory, University of Illinois, by Dr. R. N. Arnold indicated that owing to the inertia of the bending rail this number should possibly be changed to a lower value. That is, that the 40,000-lb. wheel load occurred more often than the strains measured in the field tests would indicate.

have also shown rather definite traces of decarburization in the steel near the surface of the rails.

2. Advisory Committee and Test Party: — The present membership of the Advisory committee is as follows:

Association of American Railroads – Rail Committee:

J. V. Neubert, Chief Engineer Maintenance of Way, New York Central System (Chairman)
J. E. Armstrong, Chief Engineer, Canadian Pacific Railway
W. C. Barnes, Engineer of Tests, Rail Committee, AREA
C. B. Bronson, Inspecting Engineer, New York Central Railroad
E. E. Chapman, Mechanical Assistant to Assistant to Vice-President, Atchison, Topeka & Santa Fe Railway
R. Faries, Assistant Chief Engineer—Maintenance, Pennsylvania Railroad
Maro Johnson, Principal Assistant Engineer, Illinois Central Railroad
W. P. Wiltsee, Chief Engineer, Norfolk & Western Railway
L. Yager, Assistant Chief Engineer, Northern Pacific Railway

Rail Manufacturers' Technical Committee:

F. W. Wood, 2429 Keyworth Ave., Baltimore, Md., (Chairman)
O. U. Cook, Assistant Manager, Department of Metallurgy, Investigations and Research, Tennessee Coal, Iron & Railroad Company
E. F. Kenney, Metallurgical Engineer, Bethlehem Steel Company
L. S. Marsh, Manager, Department of Inspection and Metallurgy, Inland Steel Company.
W. A. Maxwell, Jr., President, Colorado Fuel & Iron Company
C. F. W. Rys, Chief Metallurgical Engineer, Carnegie-Illinois Steel Corporation
T. H. Sanderson, Metallurgist, Carnegie-Illinois Steel Corporation

The test party carrying out the investigation includes the following:

Regular Staff:

H. F. Moore, In Charge of Investigation (Services furnished by Engineering Experiment Station, University of Illinois)
H. R. Thomas, Engineer of Tests, General detailed oversight of work, mathematical interpretation of test results, field tests
R. E. Cramer, Metallographic and chemical tests
S. W. Lyon, Laboratory tests of materials
N. J. Alleman, Laboratory tests of materials and rail specimens
J. L. Bisesi, Non-destructive detection of cracks and fissures

Test Assistants:

E. C. Bast, Chemical and metallographic tests
R. S. Jensen, Non-destructive tests

Mechanicians:

H. Belles, H. C. Boswell, F. A. Ferris, H. H. Griesheimer, M. K. Shafer and H. Musgrove

General Assistant in Machine Shop:

C. Bolcy

Student Assistants:

G. B. Bliss, R. G. Emerson, R. J. King, R. S. Hutton, E. C. Lauck, J. S. Shapland and C. Wampler

Stenographer and Clerk:

Rogene Strode

Mr. J. C. Mace, Jr., test assistant, has left the investigation to accept a position on the teaching staff of the Department of Electrical Engineering, University of Illinois.

Mr. R. J. Houkal, Mr. J. A. Nachowitz and Mr. C. M. Middlesworth have left the investigation for various positions in industry.

II. METALLOGRAPHIC TESTS

By R. E. Cramer, assisted by E. C. Bast

3. Control-Cooling Tests of Rail Specimens:—During the last year control-cooling tests of rail specimens have been made at two additional rail mills. The first tests were made at the Dominion Steel and Coal Corporation, Sydney, Nova Scotia, in March 1938 and the later tests at the Gary mill of the Carnegie-Illinois Steel Corporation, in August and December, 1938, and January, 1939.

Fig. 1. Typical Etch Test of Air-Cooled Hydrogen-Treated Rail Natural Size.
Etch 50 percent Hot HCl. Rail No. 5–0, Mill D. Ingot treated with 38 cu. ft. hydrogen. Specimen contains 240 longitudinal and 65 transverse shatter cracks on one side of a 6-in. slice.

4. Treating Ingots with Hydrogen to Produce Shatter-Cracked Rails:—In previous cooling tests it was necessary to use specimens from a large number of heats of rail steel and take the chance that some heats would develop shatter cracks in the air-cooled or "control" specimens. This was a very unsatisfactory procedure due to the time and expense involved. A method of treating rail-steel ingots with hydrogen, to cause the rails rolled from that ingot to develop a large number of shatter cracks, was developed by Mr. H. B. Wishart and associates of the Metallurgical division, Carnegie-Illinois Steel Corporation, Gary, Ind. This hydrogen treatment has been used on most of the rails used

in the cooling tests during the past year and has proven to be a valuable aid in such experiments, since in all cases when the ingots were properly treated with hydrogen the "control specimens" have developed a large number of shatter cracks during cooling in air. Fig. 1 shows an etch test of a typical hydrogen-treated rail.

5. Method of Treating Ingot with Hydrogen:—The ingot molds used were about 90 in. high, holding about 5 tons of steel, and in most cases only one ingot from a heat of steel was treated with hydrogen. The method of introducing hydrogen is shown in Fig. 2. The hydrogen from the cylinder is bubbled through a milk bottle containing mercury in order to know when the gas is flowing. The rubber stopper is wired in, and the bottle tested to over 40 lb. per sq. in. air pressure. For safety it is partly buried in a box containing cleaning waste or covered with a wire screen. The bent ¼-in. "double

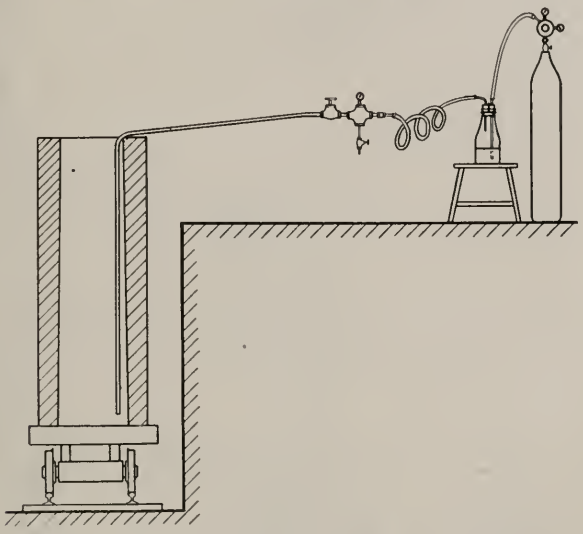


Fig. 2. Diagrammatic Sketch of Method of Treating Ingot with Hydrogen.

extra strong pipe" extending nearly to the bottom of the mold has a wall thickness of about ¼ in. which requires considerable time to melt off as the molten metal rises in the ingot mold. The hydrogen is lighted at the end of the pipe before starting to pour the ingot and to keep the pipe open, a pressure of 15 lb. per sq. in. is used when the metal first enters the mold. As the metal rises in the mold, the hydrogen pressure is increased to keep an even flow, as indicated by the bubbling of the gas in the bottle, and the pipe is moved back and forth across the mold in the molten steel. A maximum pressure up to about 30 lb. per sq. in. is necessary, depending on how fast the pipe melts away. It has been found advisable to stop the flow of hydrogen when the metal is about one foot from the top of the mold to keep the molten metal from spattering out of the mold. The pipe is usually two to four feet long when removed from the metal, depending on how fast the ingot is poured. The time of pouring has been varied from two to four minutes and this also governed the volume of hydrogen used, the latter usually varying between 25 and 40 cu. ft. While freezing, the metal gives off considerable hydrogen which burns at the top of the ingot. In the case of one ingot the solid crust was burned through

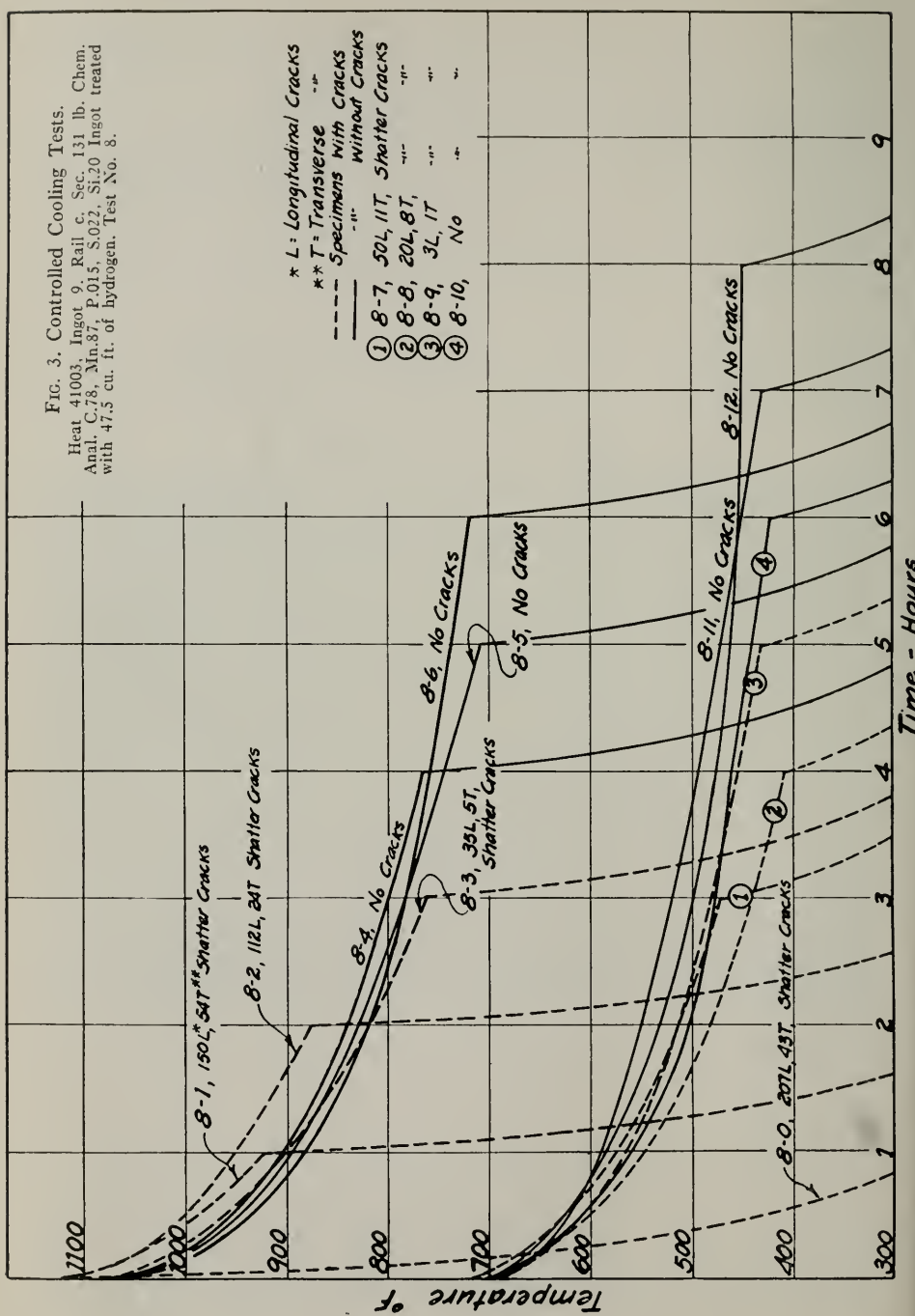


FIG. 3. Controlled Cooling Tests.
Heat 41003, Ingot 9. Rail c. Sec. 131 lb. Chem. Anal. C.78, Mn.87, P.015, S.022, Si.20 Ingot treated with 47.5 cu. ft. of hydrogen. Test No. 8.

with an oxygen jet resulting in a ½-in. stream of molten steel being thrown 5 or 6 ft. high for about a half minute, showing that considerable internal pressure is developed as hydrogen and other gases are liberated during the solidification of the steel.

6. Method of Control-Cooling Test Specimens:—A rather complete description of the method of cooling specimens was given in the Fourth Progress Report of this Investigation.[3] However, the number of boxes used in recent tests has been reduced from 20 to 12 and the investigation has purchased a 12-point temperature recorder for these tests. After three sets of specimens were tested it was quite certain that shatter cracks developed below 400 deg. F., so the boxes used to give this information have been used

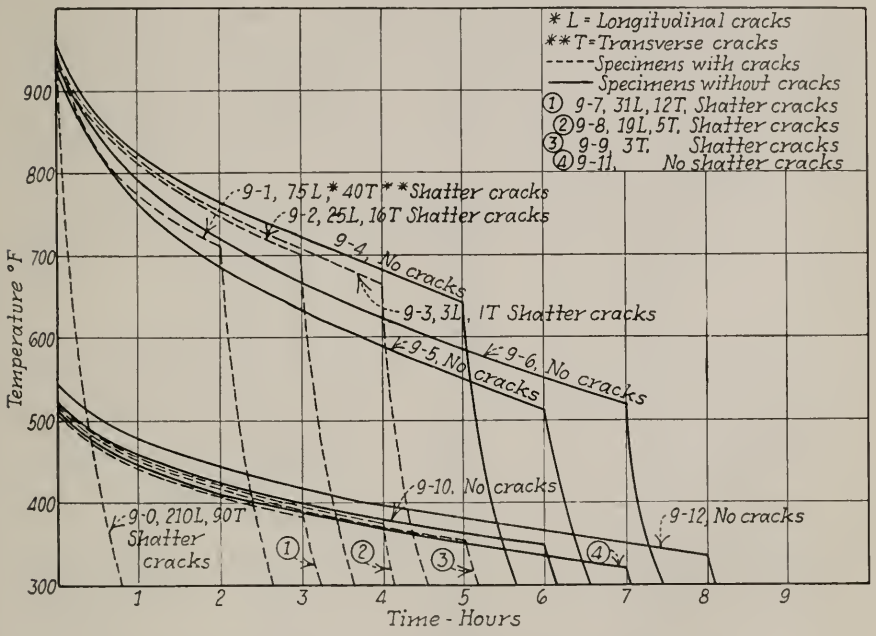


Fig. 4. Controlled Cooling Tests.
Heat 41003, Ingot 11, Rail c, Sec. 131 lb. Chem. Anal. C.78, Mn.87, P.015, S.022, Si.20 Ingot treated with 45 cu. ft. of hydrogen. Test No. 9.

in later tests to determine more closely the time necessary to hold the rails in cooling boxes to prevent shatter cracks from forming.

The cooling curves and etch test results for the last four runs made at Mill D are given in Figs. 3 and 4. Groups of six specimens were placed in the cooling boxes at each of several different temperatures and single specimens removed after different lengths of time. About 350 specimens two feet long have been used in all control-cooling tests. These specimens were from 20 heats of steel. This does not include many specimens put in the boxes and discarded because the "control specimens" did not develop shatter cracks. One or more six-inch piece from each specimen was sliced and etched for shatter cracks. The results of all box-cooling tests are summarized in Table 1.

[3] Published in Proceedings, AREA, Vol. 39, 1938, page 809.

As shown in the table the maximum time required in cooling rails in the cooling boxes to prevent shatter cracks has been seven hours and this applies only to rails put in the boxes at 500 deg. F. and 700 deg. F. It should be noted that the time values given in this table apply to *a specimen which did not develop shatter cracks*, and in the earlier experiments not enough boxes were used to tell closely the minimum time which would have prevented the cracks from forming. Also, it should be noted again that the hydrogen-treated ingots developed many more cracks when cooled in air than are found

Table 1

Summary of All Box-Cooling Tests

Number of Rails Giving Same Results	*Section of Rails Lb. per Yd.*	*Temperature of Rail when Placed in Cooling Boxes Deg. F.*	*Temperature of Rail when Removed from Cooling Boxes Deg. F.*	*Time To Reach 300° F. Which Prevented Shatter Cracks Hours*
Tests at the Ensley Mill of the Tennessee Coal, Iron & Railroad Company				
1	112	900	800	2
1	112	900	700	2
1	112	900	600	3
1	112	900	600	5
1	130	900	700	3
1	130	900	600	5
1	131	900	700	3
1	131	900	600	5
Tests at the Dominion Steel Mill, of the Dominion Steel & Coal Corporation, Sydney, N.S.				
1	100	900	700	2
1	100	900	600	3
1	100	900	600	4
1	100	900	600	*4 Hydrogen treated
2	100	900	500	5 " "
Tests at the Gary Mill of the Carnegie–Illinois Steel Corporation				
1	112	1100	935	4 Hydrogen treated
1	131	1100	765	5 " "
1	127	500	375	5 " "
1	112	500	350	5 " "
1	131	500	345	6 " "
1	131	900	640	6 " "
1	112	900	620	6 " "
1	131	700	420	6 " "
1	112	700	390	6 " "
1	131	500	360	7 " "
1	127	500	330	7 " "

* All control specimens but one from hydrogen-treated ingots contained over 100 shatter cracks in 6-in. slice.

in normally produced rails. The use of hydrogen-treated rails for the study of desirable temperatures and rates of cooling in cooling boxes involves the assumption that if controlled cooling can prevent shatter cracks in rails rolled from such abnormal metal as the hydrogen-treated steel, in which so many shatter cracks occur, then controlled cooling may be expected to be effective in preventing shatter cracks in normally produced steel,

in which, even if the rails were cooled on the hot bed, there would be few, if any, shatter cracks. It may be added that in all cases for which the test-rail specimens were from normally produced metal and for which the "control (air-cooled) specimen" developed shatter cracks,—in all these cases suitable controlled cooling prevented the formation of shatter cracks.

7. **Holding Rail Specimens at Constant Temperature**:—One of the methods which has been proposed as a treatment to prevent shatter cracks consists of holding the rails at a constant temperature below the temperature which causes decrease in Brinell hardness. Two preliminary tests have been made by the test party to investigate this method of control cooling. For this purpose six pieces of hydrogen-treated rails about three feet long were placed in a gas-heated furnace held at each of two different temperatures, 1100 deg. F. and 900 deg. F., and control specimens from the same rails were cooled on the mill floor. The specimens were removed from the furnace at one-hour intervals and cooled in air. The results of etch tests of all rails used in these tests are shown in Table 2. It will be noted that the rails held at 1100 deg. F. for 3 hours or longer did not develop shatter cracks and those held at 900 deg. F. for 4 hours or longer did not develop cracks.

Hitherto much importance has been placed on the temperature at which the rails were removed from the cooling boxes but the temperature of removal appears to be of less importance than was thought.

TABLE 2

ETCH TESTS OF 131-LB. RAILS HELD IN FURNACE AT CONSTANT TEMPERATURE

Specimen Number	*Temperature of Furnace Degrees F.*	*Time in Furnace Hours*	*Number of Shatter Cracks on One Side of 6-in. Slice L = Longitudinal; T = Transverse*	
8-20	Control specimen Cooled in air		160 L;	44 T
8-21	900	1	86 L;	14 T
8-22	900	2	55 L;	8 T
8-23	900	3	3 L;	2 T
8-24	900	4	0	
8-25	900	5	0	
8-26	900	6	0	
9-20	Control specimen Cooled in air		105 L;	45 T
9-21	1100	1	65 L;	24 T
9-22	1100	2	5 L;	
9-23	1100	3	0	
9-24	1100	4	0	
9-25	1100	5	0	
9-26	1100	6	0	

Some shatter cracks probably do form between 400 deg. F. and 300 deg. F., but if by gradual cooling the causes which produced shatter cracks are removed, then the shatter cracks will not occur at those temperatures. In the slow-cooling tests and in these constant temperature tests, a long period of gradually changing temperature, or a period of constant temperature above the temperature of crack formation, was found effective in preventing the development of shatter cracks.

8. Effect of Temperature on the Brinell Hardness of Rails:—Many tests have been made on the hardness of regular control-cooled rails with the conclusion that the present process does not appreciably affect the hardness of the rails. However, in the tests reported here some rails have been placed in cooling boxes at 1100 deg. F. and others have been placed in a furnace held at 1100 deg. F. and 900 deg. F. for periods up to 6 hours and these rails were tested for hardness. No appreciable change in hardness was found in rails held in the furnace at 900 deg. F. for 5 and 6 hours. Rails placed in cooling boxes at 1100 deg. F. and packed with rock wool insulation were 5 to 10 Brinell hardness numbers lower than those cooled in air. Rails held in the furnace at 1100 deg. F. were 25 to 30 Brinell numbers lower than those cooled in air.

9. Conclusions from Slow-Cooling Tests:—

1. In the course of the cooling tests performed at three different steel mills only a few of the heats developed any shatter-cracked rails from normal ingots, even in specimens cooled in air from rolling temperature. However, the specimens from ingots in which hydrogen had been passed through the molten steel developed many shatter cracks in the specimens which were cooled in air.

2. In the slow-cooling tests carried out at these three mills the test results showed some shatter cracks in certain of the air-cooled rail specimens, which formed between 400 deg. F. and 300 deg. F. The test rails in which shatter cracks developed at temperatures above 300 deg. F. were all from hydrogen-treated ingots of steel.

3. Rail specimens, both normally produced and hydrogen treated, held for a sufficient time above 400 deg. F. did not develop shatter cracks, even if they were removed from the cooling boxes at temperatures above 400 deg. F. A probable explanation of this is that if rails are held for a sufficient time at a temperature above that of the formation of shatter cracks, the causes of shatter cracks are eliminated.

4. The higher the temperature at which the rails are held the less time is required to eliminate the causes of shatter cracks.

5. Placing rails in cooling boxes or holding them in a furnace at 900 deg. F. does not appreciably lower the Brinell hardness. Placing rails in cooling boxes packed with rock wool insulation at 1100 deg. F. lowers the hardness 5 to 10 Brinell numbers while holding rails in a furnace at 1100 deg. F. for 5 or 6 hours lowers the hardness 25 to 30 Brinell numbers.

III. BEND TESTS FOR RAILS

By N. J. Alleman and H. F. Moore

10. Object of Preliminary Bend Tests:—In connection with the detection of shatter cracks in rails the bend test has been studied and used in the course of this investigation. It has been considered as an acceptance test for rails for the last twenty years, at least, but has not as yet received recognition by inclusion in any standard test used by railroads. During the month of November an informal conference was held in the Talbot laboratory between the test party of the Rails Investigation and a subcommittee of the American Railway Engineering Association. During this conference the limitations of the present standard drop test and certain advantages of the bend test were brought out. It was recognized that the preparation of definite specifications for acceptance or rejection of rails by the use of the bend test must be preceded by a rather elaborate series of bend tests and companion drop tests, conducted preferably at one or more steel mills in connection with regular rail rollings.

Before undertaking such tests it is evidently desirable to make studies of the effect of length of span of the bend test specimen and tests on various sizes of rail, and the

results of a few preliminary tests, made in the Talbot laboratory, are reported in this chapter. Tests with the head in tension and with the base in tension have been made.

11. Preliminary Bend Tests in the Talbot Laboratory: — The specimens tested were all from rails for which etch tests of specimens had shown no shatter cracks. Four weights of rail were studied, 90, 100, 110 and 131 lb. per yard. Three spans were used for each weight of rail, 4 ft., 4 ft. 8 in. and 5 ft. 4 in. Tests were made with specimens tested "head up" (base in tension) and "head down" (head in tension). Table 3 lists the specimens tested. All tests were made with the load applied at two points each six inches distant from the center of length of the test span. The arrangement of apparatus is shown diagrammatically in Fig. 5. The advantage of the two symmetrical loads is that with such loading there is a length between the loads over which the bending moment and stress-distribution in the specimen remains constant. The tests were made on the 600,000-lb. Riehle screw-power beam-balance machine in the Talbot laboratory.

12. Data on Bend Tests:—Table 3 gives the data of the specimens tested. To eliminate the effect of varying strength of steel in the different specimens, tensile test specimens were cut from a corner of the head and from the flange, outside of the web, and the values for strength (load for fracture) were "adjusted" to a standard tensile strength of 125,000 lb. per sq. in. Similarly the values for ductility were "adjusted" to a standard ductility of tensile test specimen of 14 percent elongation in a two-inch gage length. Energy for fracture was "adjusted" on the basis of the product of standard strength and standard ductility. Complete data of the tensile tests of specimens are not given in this report owing to the great space required. They are on file with the test party, as are the original autographic load-deflection diagrams.

13. Results of Bend Tests:—Table 4 shows the "adjusted" results of the bend tests, and Figs. 6 and 7 show these results graphically. In Fig. 6 test results are plotted to show the effect of length of span on test results. The load necessary for fracture is seen to vary inversely as the length of span, with a fair degree of consistency. When energy for fracture is plotted against span, the head-down tests for spans not greater than 4 ft. 8 in. show energy varying directly with span. For the head-down tests the 110-lb. and the 131-lb. rail specimens show this relation up to and including a span of 5 ft. 4 in.

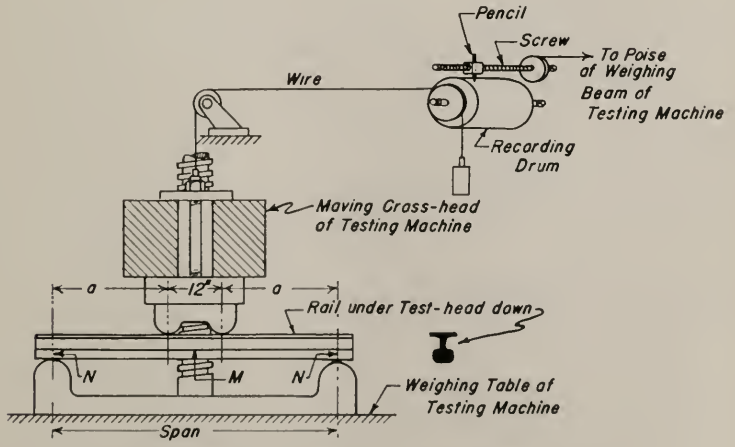


Fig. 5. Diagram of Test Rig for Bend Test of Rails.

TABLE 3

RAILS USED FOR BEND TEST SPECIMENS

Lab. No. of Rail	Mill and Weight of Rail	Heat No.	Mill No. of Rail	Treatment of Rail	Heat Analysis values in percent					Brinell No. Top of Head	Tensile Strength lb. per sq. in.	
					Carbon	Manganese	Silicon	Sulphur	Phosphorus		Spec. from head	Spec. from base
1062	B–131 lb.	215,137	B 12	Cont. cool	0.75	0.76	0.19	0.029	0.024	266	135,900	138,100
1067	E–131 lb.	27,296	E 9	Hot bed	0.73	0.80	0.15	0.027	0.024	266	131,600	134,500
705	D–110 lb.	33,013	F 13	Hot bed	0.71	0.72	0.29	0.023	0.028	259	128,000	121,900
703	D–110 lb.	33,013	A 13	Hot bed	0.71	0.72	0.29	0.023	0.028	266	131,400	134,800
728	F–100 lb.	869,451	F 5	Hot bed	0.67	0.75	0.20	0.022	0.027	247	120,700	117,200
729	F–100 lb.	869,451	E 18	Hot bed	0.67	0.75	0.20	0.022	0.027	252	122,100	123,000
747	F–100 lb.	899,217	A 23	Asb. cover	0.75	0.87	0.20	0.027	0.032	282	137,900	142,100
753	F–100 lb.	899,225	A 23	Hot bed	0.67	0.73	0.20	0.025	0.030	256	124,600	125,900
725	F– 90 lb.	869,453	C 19	Fan cool	0.72	0.75	0.18	0.025	0.039	258	126,500	129,500
727	F- 90 lb.	888,315	B 17	Fan cool	0.70	0.78	0.20	0.028	0.036	259	127,300	129,900

TABLE 4

RESULTS OF BEND TESTS OF RAIL SPECIMENS

In all tests the load applied to the specimen consisted of two equal loads, one six inches to one side of the mid-length of the span of the specimen and the other six inches to the other side.

The test rig used is shown in diagram in Fig. 2 of the Second Progress Report of the Rails Investigation (1936).

All rail specimens tested were free from shatter cracks as indicated by etch tests of six-inch specimens cut from the rail. All test results have been adjusted to a tensile strength of steel of 125,000 lb. per sq. in. and to an elongation in 2 in. (on a tensile specimen ½ in. in diameter) of 14 percent.

Lab. No. of Rail	Weight lb. per Yard	Span, 4 ft. 0 in.			Span, 4 ft. 8 in.			Span, 5 ft. 4 in.		
		Max. Load lb.	Deflection at Fracture in.	Energy for Fracture ft.-lb.	Max. Load lb.	Deflection at Fracture in.	Energy for Fracture ft.-lb.	Max. Load lb.	Deflection at Fracture in.	Energy for Fracture ft.-lb.
Specimens Tested Head-down (head in tension)										
1062	131	448,000	6.49	199,300	362,200	8.13	206,000	299,000	10.00	212,000
1067	131	457,000	6.33	196,300	363,800	8.07	206,500	304,300	10.08	219,500
703	110	344,200	6.60	154,500	279,500	8.12	157,000	230,300	10.37	170,500
705	110	334,500	6.62	154,300				222,800	10.61	169,600
728	100	303,000	6.96	147,000	240,800	8.96	152,800	206,800	8.25	113,800
729	100	312,100	5.93	124,000	250,300	8.52	148,300	213,300	8.94	127,000
725	90	253,000	6.58	114,500	201,500	8.75	125,300	167,000	6.15	65,300
Specimens Tested Head-Up (base in tension)										
1062	131	458,200	9.22	262,200	350,100	10.35	224,500	283,900	9.08	173,000
1067	131	447,000	6.67	199,000	360,200	10.17	230,800	288,800	10.68	195,800
703	110	344,100	5.34	115,300	281,000	6.55	116,500			
705	110	399,600	6.86	178,000				262,000	10.10	179,000
747	100	305,000	6.80	138,700				192,000	9.17	123,600
753	100	310,000	6.31	132,800				190,400	7.06	93,600
727	90	239,500	5.44	88,750				162,800	7.92	89,600

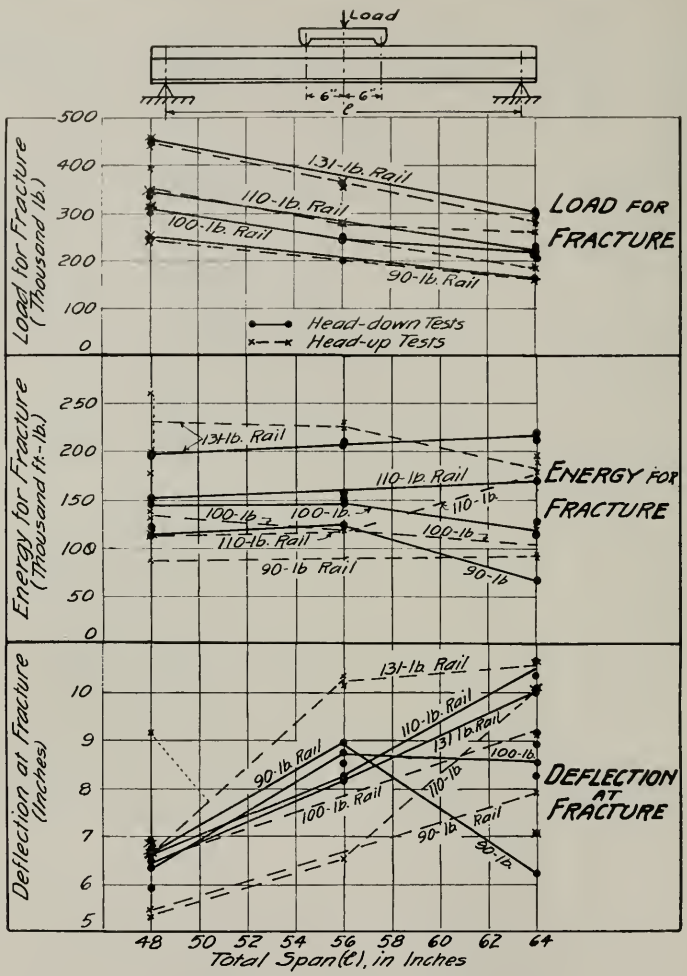


Fig. 6. Bend Tests of Rails – Effect of Span.

Beyond 4 ft. 8 in. some results for the lighter rails become erratic. The energy for fracture developed in the head-up tests also shows some erratic test results for the 5 ft. 4 in. spans tested.[4]

This irregularity of action on the longer spans is probably caused by the tendency of a compression flange of any beam to buckle sidewise. In the bend test rig used at the University of Illinois the only restraint on sidewise buckling is the friction of the bearing block on the compression (upper) side of the specimen. On the under side—the tension side – the tendency would be to offer a slight resistance to buckling. Now in the head-up test the compression side is the head, it is narrower than the base, and the bearing block

[4] It will be remembered that previously reported bend-test results used to detect shatter cracks were all for head-down tests.

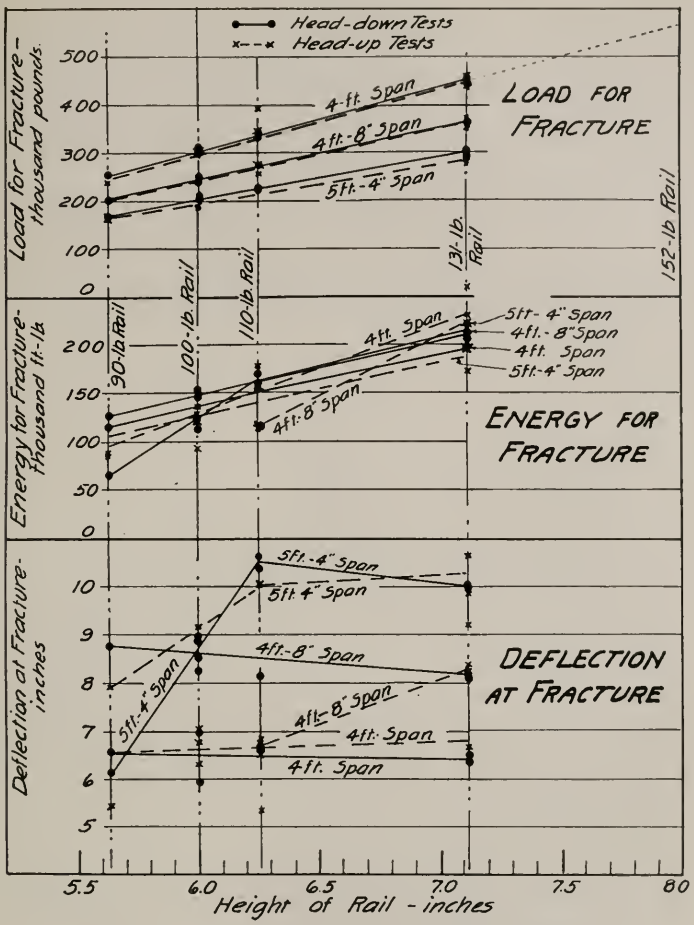


Fig. 7. Bend Tests of Rails – Effect of Size of Rail.

touches it only at one point of its curved surface, hence the results of head-up tests might be expected to be more erratic than those of the head-down tests.

This is the case when deflections at fracture are examined. It seems desirable to make head-up bend tests using some stronger lateral restraint at the center of length of the speicmen than is afforded by the friction of the compression block of the testing machine.

In view of the erratic results with some specimens with spans of 5 ft. 4 in. it seems desirable to use a 4-ft. span for testing 110-lb. and 131-lb. rail specimens, especially in view of the erratic deflection of the specimens with the base in tension over a 5 ft. 4 in. span. For 90-lb. rail and, perhaps, for 100-lb. rail, spans of 3 ft. or 3 ft. 6 in. might be better. If 152-lb. rail is to be given a bend test using a 4-ft. span the load for fracture might reach 600,000 lb. or more. (See Fig. 6, upper part). Possibly a span of about 5 ft. would be suitable.

In Fig. 7 the results of bend tests are plotted with depths of rail as abscissas. The choice of depth of rail as a co-ordinate is, of course, arbitrary. If the rail behaved as an

elastic body up to, or nearly up to fracture, the section modulus (moment of inertia divided by distance from neutral axis to extreme tension fiber) would have been used. However, the rail specimen does not behave as an elastic body up to fracture. In view of the general similarity of form of rail sections, in view of the great influence of depth on the deflection of the rail, and in view of the general tendency of inelastic action to cause stress distribution in any flexural member to become more nearly uniform than is the case under elastic bending, depth of rail was chosen for abscissas.

It is, of course, quite out of the question to propose any specifications for the bend test of rails on the basis of the few tests here reported. However, to give some idea of the order of magnitude of loads, deflections, and energies for fracture involved in bend tests the following tabulation for average head-down bend tests of rails using a total span of 48 in. with two equal loads spaced 6 in. on either side of the mid-length of the span may be of service.

Weight of Rails lb. per yd.	*Load for Fracture lb.*	*Deflection at Fracture in.*	*Energy for Fracture ft.-lb.*
90	250,000	6.60	116,000
100	305,000	6.50	135,000
110	340,000	6.60	154,000
131	450,000	6.40	200,000

14. Further Study of Bend Tests:—The tests described in this report are to be regarded merely as a few preliminary tests. They indicate that bend tests of rails might well be made on specimens with a span of 4 ft., with possibly somewhat longer spans for rails heavier than 131-lb. per yard. To avoid buckling of the compression flange it seems desirable, for head-down tests, to use a span not greater than 4 ft. 8 in., and for head-up tests it seems desirable also to study methods of restraining the head from buckling during the test. Using a 4-ft. span, it seems that deflections of an order of magnitude of about 6.5 in. may be expected. This means that it will not be necessary to use any delicate deflection-measuring device. It seems that the loads required to cause fracture will have an order of magnitude of about 250,000 lb. for 90-lb. rails up to 450,000 lb. for 131-lb. rails, that is, a bend-testing machine should have a capacity of at least 600,000 lb.

If an attempt were made to formulate specifications, consultation and if possible arrangements should be made with one or more steel mills to run bend tests along with drop tests for several heats of rails rolled by them. It would be desirable to have representatives of the test party present at such tests.

15. General Consideration of Drop Test and Bend Test:—During the conference with the subcommittee of the Rail committee of the AREA the following appraisal of values and disadvantages of each test was brought out:

The Drop Test

(1) As at present conducted the drop test is merely a "pass or fail" test, and it gives very little indication of the relative merit of different rails which pass the test.

(2) If the use of repeated blows to fracture a rail specimen were made a required test (instead of an optional test for information only), it would be possible to measure total energy drop only in "steps" of about 40,000 ft.-lb. Moreover, after the first blow the specimen is so distorted that any accurate determination of stress or energy under succeeding blows is not possible, and the relative effect of successive blows and of one blow heavy enough to cause fracture is not known.

(3) In the standard M.C.B. drop-testing machine there is a large amount of energy absorbed in the springs supporting the anvil. The amount of this energy could be measured by measuring the deflection of the springs in each test, but that is not done, and it is probable that this energy in the springs varies with different machines. This energy is not absorbed by the specimen. If a rail of high elastic strength (e. g. an alloy steel rail) is tested, a decidedly brittle rail may pass the drop test. Within its elastic range a rail absorbs very little energy, — the springs absorb most of the energy until the specimen begins to take permanent set. Thus most of the energy of drop of the tup may be absorbed by the springs.

(4) While it would be possible to modify the drop test by requiring the determination of energy absorbed by the springs and deducting that amount of energy from the total energy of the falling tup, this would add to the complexity of the test procedure, and the impossibility of determining resistance of specimen except in wide "steps" of energy would remain.

The Bend Test

(1) From several experimental studies[5] there is considerable evidence that a bend test using an autographic load-deflection record gives a measure of energy required for fracture not widely different from that given by a single-blow impact test to fracture, unless the speed of the striking hammer is much higher than that due to a free fall from a height of 22 ft. (height for M.C.B. drop test for 131-lb. rail). In the M.C.B. drop test the speed of application of stress to the specimen is further retarded by the time required for deflection of the springs under the anvil.

(2) The bend test gives a measure of *strength* of the rail specimen (inch-pounds bending moment, or pounds per square inch nominal stress in extreme fiber) which is *not* determinable from drop-test data. Measurements of ductility (elongation on tension side of specimen) and of toughness (area under load-deflection diagram) are both determinable from the data of the bend test.

(3) The time required to make a bend test with a testing machine provided with a powerful hydraulic pump or a high-power screw drive would probably be slightly greater than the time required to make a drop test. However, it should be noted that the long time required to make bend tests at the University of Illinois is due to the relatively low-power drive on the testing machine available there. Strength of bend-test specimen can be determined directly from the autographic load-deflection diagram, and toughness (energy for fracture) can be readily determined by measuring the area of the diagram with a planimeter. In the bend test the deflection of the specimen is so large that no delicate measuring apparatus is required.

(4) The first cost of a bend-test machine would be somewhat greater than that of a drop-test machine, but it should be noted that the cost of a single-purpose bend-test machine should be much less than the cost of a "universal" testing machine (e.g. such a machine as the 600,000-lb. machine at the University of Illinois, or the one at Gary).

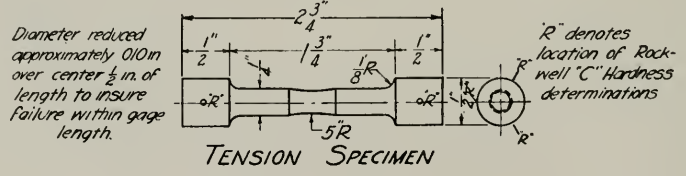
[5] Petrenko, S. N., "Comparative Slow-Bend and Impact Notched-Bar Tests on Some Metals." National Bureau of Standards, Technologic Paper No. 289 (1925).
Moore, H. F., Wishart, H. B. and Lyon, S. W., "Slow-bend and Impact Tests of Notched Bars at Low Temperatures." Proceedings, ASTM, Vol. 36, Part II, p. 110 (1936).
Mann, H. C., "High Velocity Impact Tests." Proceedings, ASTM, Vol. 36, Part II, p. 85 (1936).

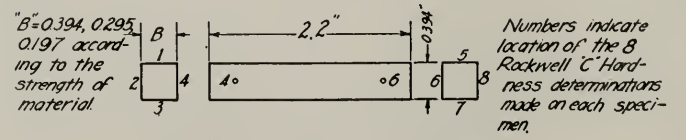
IV. EFFECT OF HEAT TREATMENT ON THE MECHANICAL PROPERTIES OF HEAT-TREATED RAIL STEEL

By S. W. Lyon

16. Outline of Problem:—The application of the various end-hardening processes to railroad rails to produce a hardened condition in the rail ends, thereby to better resist battering action at rail joints under traffic in track, consists essentially of the practical application of the principles of heat treatment to rail steel. Any study then, which has for its purpose the determination of the most desirable mechanical properties to be attained in the hardened material of end-hardened rails so as to best resist batter, resolves itself into a study of the effect of heat treatment on the mechanical properties of rail steel.

Such studies could have been made by testing specimens machined from the hardened portions of rails end hardened to cover a range of hardness by the various end-hardening processes. However, the extreme difficulty and expense of machining specimens from end-hardened rails, especially for the higher hardnesses, practically precluded this procedure as a feasible method of attack. Consequently a laboratory method was adopted whereby specimens were cut from unhardened rails, heat treated to produce any desired range of hardness, and then tested so as to give surveys of the various properties. This method while not in all phases reproducing conditions in the steel obtained in actual end-hardened rails (i.e., mass effect in heat treatment, etc.) will,




"B"=0.394, 0.295, 0.197 according to the strength of material.
B
2.2"
.0394"
Numbers indicate location of the 8 Rockwell "C" Hardness determinations made on each specimen.
IMPACT BENDING SPECIMEN

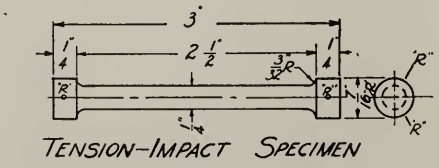


Fig. 8. Test Specimens.

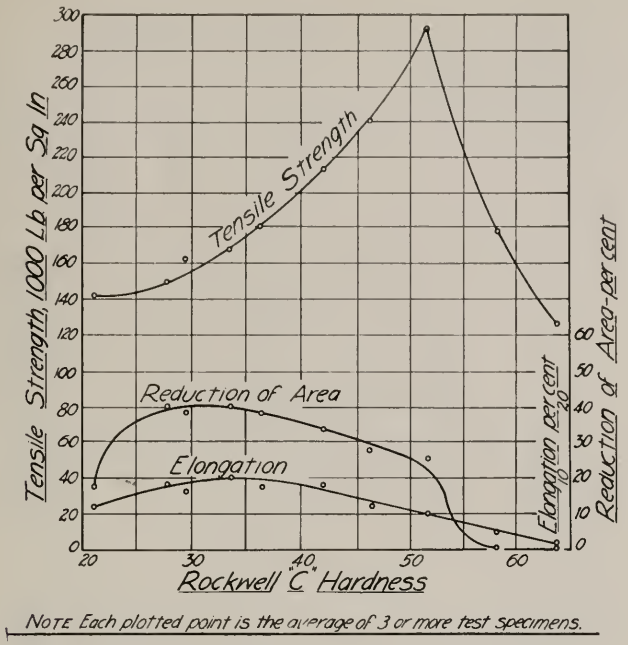

Tensile Strength, 1000 Lb per Sq In
Tensile Strength
Reduction of Area
Elongation
Elongation per cent
Reduction of Area per cent
Rockwell "C" Hardness
NOTE Each plotted point is the average of 3 or more test specimens.

Fig. 9. Tensile Strength, Reduction of Area and Elongation vs. Rockwell "C" Hardness.

it is felt, especially when interpreted in conjunction with the rolling-load test results and the future field results, give significant information looking toward the formulation of end-hardening standard practice.

The mechanical properties of heat-treated rail steel studied and the methods used are briefly as follows: Tension specimens were prepared and tested to study the variation of tensile strength, percentage elongation, and percentage reduction of area. Impact-bending tests of unnotched bars and impact-tension tests were used to determine variation of toughness[6] with hardness changes. Impact-bending tests of unnotched specimens tested at temperatures varying from +70 deg. F. to —70 deg. F. provided information on the effect of temperature on the toughness of rail steel.

17. Testing Procedure and Test Specimens:—The specimens for the various tests were machined from Rails 1105 and 1074, as these rails had been shown by previous etch tests to be free from shatter cracks and by analysis to be in the mid-carbon range. In order to insure, as far as possible, that the material used should be of uniform quality, all specimens were cut from the heads of the rails adjacent to the tread.

Fig. 8 shows the various types of test specimens used. The specimens were machined to within 0.010 in. of finished dimensions, heat treated to produce the desired hardnesses and then finish-ground to size. Hardness readings were then taken on all specimens prior to testing. The general procedure of heat treatment was to quench all specimens to obtain maximum hardness, followed by suitable draw to obtain the desired hardness.

[6] The term "toughness" is used to denote energy required to fracture a metal.

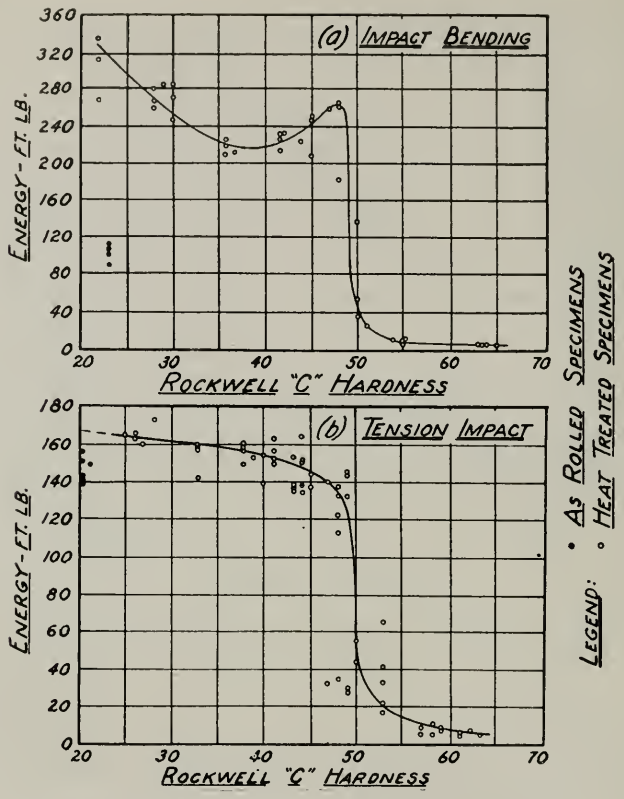

(a) Impact Bending
Energy - Ft. Lb.
Rockwell "C" Hardness
(b) Tension Impact
Energy - Ft. Lb.
Rockwell "C" Hardness
Legend: • As Rolled Specimens ○ Heat Treated Specimens

Fig. 10. Impact Test Results vs. Rockwell "C" Hardness.

To determine the variation of toughness of rail steel with change of temperature, the energy developed in impact-bending tests of unnotched specimens was considered as the criterion of toughness. The variation of toughness with change of temperature was obtained by determining the impact-bending results vs. Rockwell "C" hardness relationships for five testing temperatures, namely, +70 deg. F., +30 deg. F., 0 deg. F., —30 deg. F. and —70 deg. F. Briefly, the testing procedure consisted of bringing the specimens to the desired temperature in a bath of acetone cooled with dry ice (solid CO_2), quickly placing them in the Charpy-impact testing machine and testing before appreciable temperature fluctuation was possible.

18. Results of Tests:—Fig. 9 gives the results obtained from the tension tests.[7] Examination of the curves will show that the maximum values of tensile strength were obtained at a hardness of approximately Rockwell "C" 52 (or Brinell 483). Values of reduction of area also fell off rapidly when the hardness of 52 was exceeded while elongation values decreased more slowly.

[7] These tension-test results, which were previously presented in the AREA Proceedings, Vol. 39, 1938, page 824, are repeated here to give a more complete picture of the effect of heat treatment on the mechanical properties of rail steel.

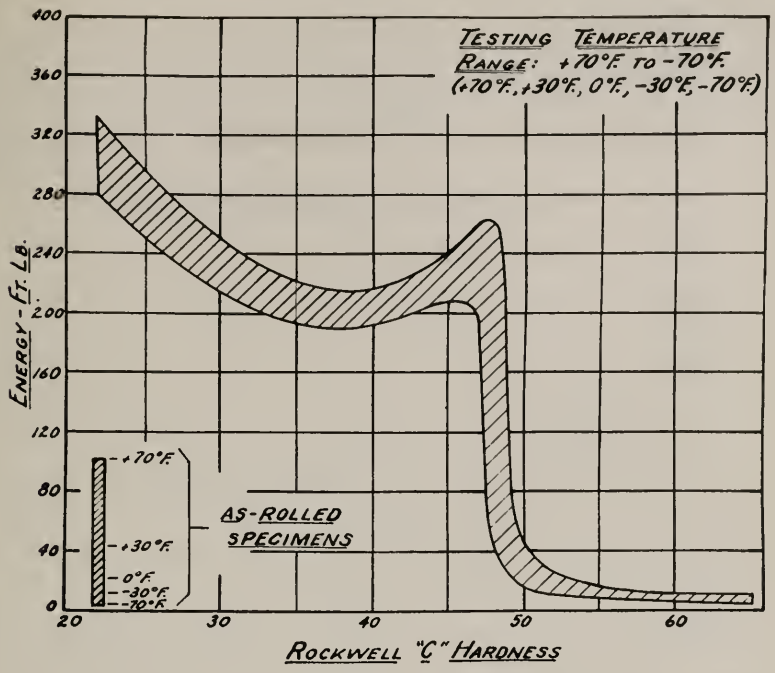


Fig. 11. Envelope Showing Variation of Rockwell "C" Hardness vs. Charpy Impact Bending Strength Relationships Caused by Varying Testing Temperatures between +70 deg. F. and –70 deg. F., Unnotched Bars.

The results of the impact-bending and tension-impact tests for unnotched test specimens of varying hardness are given in Fig. 10 (a) and (b). Considering these test results as a criterion of toughness it can be observed that the toughness of heat-treated rail steel drops off rapidly when the hardness of Rockwell "C" 48 (or Brinell 445) is exceeded. It should be noted also that for the heat-treated specimens, as the hardness decreases the toughness increases.

Fig. 11 shows the effect of temperature on the toughness of heat-treated rail steel as determined by the impact bending vs. hardness relationships obtained for five testing temperatures. The envelope, which gives the variation of toughness, was constructed by superimposing the impact-bending vs. hardness curves for the five temperatures and then enclosing all five curves. These results would indicate that the toughness of heat-treated rail is not greatly changed over the range of temperature between +70 deg. F. and —70 deg. F. Also, for this temperature range the envelope indicates that to have good toughness heat-treated rail steel should not exceed Rockwell "C" 47 in hardness.

In the lower left corner of Fig. 11 are shown the impact-bending results obtained for the five testing temperatures on specimens of the as-rolled rail. Fig. 12 compares these results with those obtained for the heat-treated specimens of similar hardness (Rockwell "C" 22). Examination of the curves shows that at all testing temperatures the heat-treated steel had much greater toughness than the as-rolled steel. It should also be noted that as the temperature at the time of testing is progressively lowered the

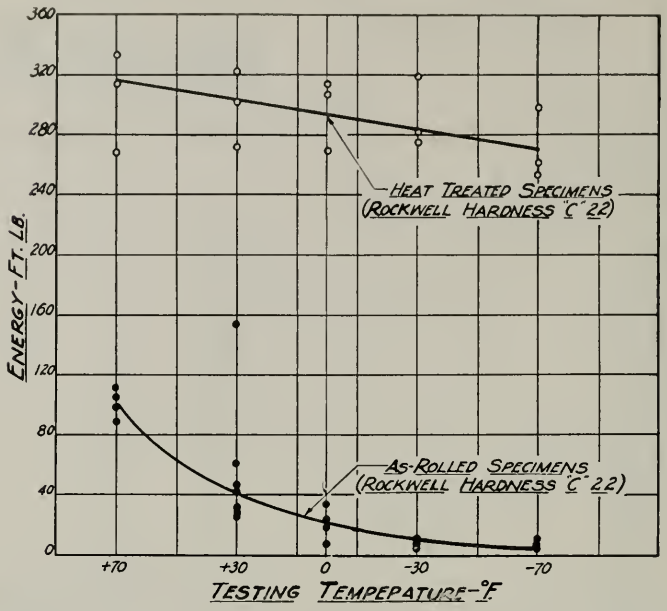


Fig. 12. Comparison of Variation of Charpy Impact Strength of Heat Treated and As-Rolled Specimens of Rail Steel Tested over a Range of Temperature of +70 deg. F. to −70 deg. F.

The Heat Treated Specimens and the As-Rolled Specimens both have an Average Rockwell Hardness of "C" 22.—Unnotched Bars—

as-rolled material loses its toughness much faster than does the heat-treated steel. These results indicate then, that the heat treatment of the rail steel tested produced two beneficial results, namely, the toughness was much improved over that of the as-rolled steel and the effect of temperature was much less for the heat-treated material over the range of temperatures considered. From a practical viewpoint the significance of these results would be that in end-hardened rail ends, even though the hardness should not be sufficient to properly prevent batter, the added toughness imparted to the rail ends might be expected to be helpful in preventing chipping in cold weather.

19. Summary:—The tension test results, the impact-bending and impact-tension test results and the impact-bending results for a temperature range of +70 deg. F. to —70 deg. F. all show that heat-treated rail steel loses strength, ductility, and toughness rather suddenly in the range of Rockwell hardness of "C" 47 to "C" 52. This would indicate that the usable hardness of the heat-treated steel is exceeded when a hardness of approximately "C" 47 is exceeded.

As the hardened material in end-hardened rails is rather carefully heat-treated rail steel, it seems reasonable to assume that the toughness in end-hardened material would be subject to the same hardness limitations. In other words it is indicated that the *upper limit* of Rockwell "C" hardness to be attained in end-hardening practice should not exceed a value of "C" 45 (or Brinell 415).

Heat-treated rail steel developed good toughness for hardnesses below "C" 45 at all testing temperatures. This would point out that the lower limit of hardness for end-hardening practice would not be set by toughness considerations. The rolling-load

tests (and service tests) indicate that hardnesses in end-hardened rails below "C" 35 (or Brinell 320) are not effective in preventing wear and batter. Briefly then, the limits of hardness seem to be set on the high end by *toughness considerations* and on the lower end by *batter* and *wear considerations*. The laboratory tests at this time indicate a satisfactory hardness range between "C" 35 and "C" 45, (approximately Brinell 320 to 415).

V. NON-DESTRUCTIVE TESTS

By J. L. Bisesi, Assisted by R. S. Jensen and G. B. Bliss

20. Vibration Tests:—During previous tests, described in preceding reports, it was thought that if more power could be supplied to a test rail it would result in an increased amplitude of vibration, and better results would be obtained. With this object in mind, new vibrating equipment was designed using more and larger power-tubes which were capable of giving three times as much power as the ones previously used. Also, the old driving coil was replaced by a larger one which was mounted on a new support designed for much finer adjustment. The method of vibrating the rail was the same as with the old equipment, and the same testing procedure was followed as described in previous reports. As an extra precaution to insure the same conditions for each rail, bakelite spacers were used to set the coils the proper distance from the ends of the rail. Tests have been nearly completed with the more powerful equipment and results have been obtained for the following rails: 110-lb. rails, 6 shatter-cracked, 18 clear, 24 in all; 130-lb. rails, 15 shatter-cracked, 13 clear, 28 in all; 131-lb. rails, 4 shatter-cracked, 6 clear, 10 in all.

The curves of amplitude vs. time from which the data for the damping values are obtained, appear to follow the trend of the results previously reported. As before, the curves for the 110-lb. rails show a fairly definite zone in which the clear rails seem to fall. Also as before two of the shatter-cracked rails, 702 and 594, fell in this zone. Rail 636, a clear rail, falls among the shattered rails. These results show an accuracy of 87.5 percent. Rail 702 may be a border-line case having few shatter cracks but 594 had quite a few shatter cracks. On the other hand the curves for the 130-lb. and 131-lb. rails still continue to show no differentiation between the shattered and clear rails.

The plotting of the average damping factors of the various rails tested yields results similar to those previously reported. In the case of the 110-lb. rails all of the clear rails have average damping factors between 0.045 and 0.08. However, the average damping factors of shatter-cracked rails 702 and 594 are also within those limits. The average damping factors for the 131-lb. rails indicate that the clear rails fall within the limits of 0.0455 and 0.0495. There are no exceptions in this case. The 130-lb. rails, however, do not show any such zone.

These are the most encouraging results thus far obtained, but they still indicate that there are some factors which influence the damping to a greater extent than does the shatter-cracked condition. In view of this, unless some discovery is made to clarify the situation the vibration tests will be discontinued and other methods of attack will be tried after the completion of the tests on the remaining rails.

21. Echo Method:—One of the suggestions which have been made was to study the echo method of discovering discontinuities. This test was suggested by Mr. F. M. Graham, assistant engineer of standards of the Pennsylvania Railroad. In this method a blow is struck on the end of the rail by a hammer. It is thought that if the rail

contains shatter cracks the pattern of the primary pulse of vibration will contain superimposed secondary waves, reflected from the shatter cracks. The equipment for this test is not completed as yet, but it is in the process of construction.

22. Detector-Car Operation:—The operation of the detector cars over the test rail in service has been followed up this year as in the past. During the past year all of the test rails, both on the Baltimore and Ohio Railroad and the Santa Fe Railroad, have been gone over with detector cars, the rail on the Santa Fe having been tested twice during 1938. The tests are progressing satisfactorily in that the rails on the Baltimore and Ohio, being subjected to heavier wheel loads, are beginning to

TABLE 5

110-LB. TEST RAILS REMOVED FROM ATCHISON, TOPEKA & SANTA FE RAILROAD TRACK

Heat No.	*Ingot*	*Letter*	*Mill*	*Cause of Removal*
14025	7	C		
14025*	9	C	C	Curve-worn
16030	19	B		
16030*	19	E	C	Curve-worn
16030	25	B		
41014	14	F		
41014	14	C	D	Curve-worn
41014	14	B		
36013	14	F		
36013	14	E		
36013	14	C	D	Curve-worn
36013	15	B		
18583	14	H		
18583	20	B	E	Crushed head
24439	14	H	E	Crushed head
25518	19	H	E	Crushed head
14025	11	C		
7028*	2	B	C	Stock rail
15694*	10	F	E	Stock rail

* Samples of these rails are being sent to the laboratory for further study. A report on laboratory studies of some of the other rails has been presented.

show fissure failures, whereas those on the Santa Fe being subjected to relatively lighter wheel loads, have come through without fissure failures. It should be noted that laboratory samples taken from all the heats from which any rails have failed on the Baltimore & Ohio Railroad contained shatter cracks. The laboratory etch test samples were those obtained at the steel mills at the time the rails were rolled. The occurrence of these failures brings to light a rather encouraging correlation, at least for the rails

on the Baltimore & Ohio north of Dayton, between the rolling-load tests made in the laboratory, the wheel-load tests made at Dayton, Ohio in 1933 and the service failures. This is discussed following the notes of the detector car operation over the test rails.

A. *Atchison, Topeka and Santa Fe Railroad*—Middle Division Ellinor to Matfield Green:—The test rail on the Santa Fe comprising 21 miles of track was laid in 1932. This is single-track territory carrying freight on the cut-off between Ellinor, Kan., and Eldorado. This rail was laid in August, September and October of 1932 and has been tested each year by means of the company-owned Sperry-type Detector Car. The last test was made in December, 1938. No defective rails have been found on any of the test runs, but 21 rails have been removed from service for various reasons and are listed in Table 5. At the time of the last detector-car run, 88.6 milion tons of traffic had been carried.

In Table 5, the rails from Mill C and the stock rails were removed from track during 1938, the others had been removed in previous years. It will be noted that all of the rails removed from service because they were curve worn were rolled in Mills D and C. The rails from Mill D were laid in the section of track containing the most curves while those from Mill E were laid in track containing the fewest curves.

B. *Baltimore & Ohio Railroad:*—The test rails on the Baltimore and Ohio Railroad were laid in seven locations, on three divisions of the road as shown in Table 6. The Sperry equipment operated over these rails in November and December of 1938. In all sections of the test rail except that on the Toledo division, double-crew testing was used. The tests on the Toledo division were completed by the single-crew method of testing. All indications except those on the Pittsburgh division were checked by the drop-of-potential method. In testing on the Pittsburgh division the drop-of-potential car was about two weeks behind the first car which made the record, and this rail is laid on a section containing many curves. Because of these conditions the crew was allowed to proceed as it would in normal testing procedure.

An accumulative record of the failures in the test rails in service on the Baltimore & Ohio is given in Table 6. It may be seen in this table that out of 24 failed test rails removed from track, 17 contained transverse fissures, 4 had horizontal split heads and 3 had vertical split heads. Another fact to be observed from this record is that the rails from Mills E and A are beginning to show signs of failure. The rails from these mills, which are laid in track near Troy, Ohio, and which are beginning to fail, are those laid in October, 1935, and March, 1936, respectively and have had very little service as compared with rails from Mills D and E which were laid from 1932 to 1934. The reason for this may be due to the possibility that on the Toledo division the relative number of large wheel loads has increased or that the wheel loads are greater at this location than at the test location near Vandalia.

The observation of the operation of the detector cars over the test sections will be continued.

23. Progressive Fatigue Cracks Originating at Driver Burns:—During the tests on the Baltimore & Ohio Railroad the Sperry-test crews have encountered a number of fatigue cracks (detail fractures) which apparently started at driver burns in the rail and progressed downward. These cracks are visible just as often on the side of the head as they are on the tread in the burned area. Their number is small as compared to the number of driver burns on the rail, but it is possible to conceive that a rail failure might occur at such a defect. None of these failures has been found on the test sections, but the fact that they have been found elsewhere adds to the reasons for the checking of *all* indications on the Sperry record tapes. Samples of these failures are now in the laboratory for investigation.

TABLE 6

ACCUMULATIVE RECORD OF FAILURES ON BALTIMORE AND OHIO RAILROAD TEST RAIL

Division	Location	Track	No. of Rails	Date Laid	Mill	Heat	Failures			Million Tons	Total Failures	Etch Tests***
							Cause					
							T.F.	H.S.H.	V.S.H.			
Toledo	Dayton to Vandalia	Single	1,529	2–32	D	50110	0	0	1	58.9	1	Heat 50110
						50110	1	0	0	73.0	1	44 L; 30 T
	M. P. 62.5 to 68.1					43118	1	0	0	73.0	1	Heat 43118
						50110	3	0	0	89.2	3	7 L; 4 T.
						43118	3	0	0	89.2	3	
						50110	5	0	0	109.7	5	
						43118	0	0	1	109.7	1	
	Tipp. City to Troy	Single		5–34			No Failures					
	M.P. 72.9											
	73.8, 74.0, 76.0		804								0	
										80.4		
	73.8–74			1–35			No Failures				0	
	76 –76.4		53	10–35	E	27525	0	2	0	57.4	2	8 L
	76.4–78.1		657	3–36	D	47248	1	0	0	50.4	1	2 L
Pittsburgh	Layton to St. James	No. 2	1,108	12–33			No Failures			62.8	0	
Cumberland	Bardane to Kearneysville	No. 2	371	7–33	A	74098	1	1	0	92.5	2	7 L
						75102	0	1	0		1	2 L
	Kesslers Bridge to Okonoko*	No. 3	1,625	8–33	A	74191	0	0	1	68.3	1	1 L
						74190	2	0	0		2	3 L
	Hansrote Patterson**	No. 3	51	7–33			No Failures			68.9	0	
	Creek Cut-off	No. 4	142	3–32			No Failures			1.5	0	

* One additional rail, Heat, 209,137, 6 C, Mill B removed because of excessive burns.
** Service discontinued.
*** Number of longitudinal (L) and transverse (T) cracks found in one six-inch slice from samples shipped to the laboratory at the time of rolling.

24. Correlation of Rolling-Load, Wheel-Load and Service Tests on Rails North of Dayton:—The development of transverse fissures in the test rail on the Baltimore & Ohio Railroad recalls the question of correlation of the various test data. This discussion is based largely on the discussion of the results of the field tests to determine wheel loads made north of Dayton in 1933. The list of failed rails found in this section of track is given in Table 7, together with the amount of traffic which these rails have carried and the dates the failures were found.

TABLE 7

FAILED 130-LB. TEST RAILS—TOLEDO DIVISION, NORTH DAYTON TO TROY

Heat No.	*Defect*	*Tonnage Millions*	*Date Found*	*Remarks*
47248	1 T. F.*	50	Dec. 1938	Found by Sperry detector car
27525	2 H. S. H.*	59	Dec. 1938	
50110	1 V. S. H.*	58.9	May 1936	
50110	1 T. F.	73	Nov. 1936	Service failure
43118	1 T. F.		Nov. 1936	
43118	3 T. F.			
50110	3 T. F.	89.2	Sept. 1937	Found by Sperry detector car
50110	5 T. F.			
43118	1 V. S. H.	109.7	Dec. 1938	

* T.F., denotes transverse fissure; H.S.H., horizontal split head; V.S.H., vertical split head.

Heats 47248 and 27525 were laid in March 1936 and October 1935, respectively, after having lain on the ground since they were rolled in 1932. Therefore, although the failures were found in December 1938 they had comparatively little tonnage over them.

In the laboratory, the rolling-load tests were carried out in an attempt to give some estimate of the number and magnitude of wheel loads necessary to start and develop an internal fissure in a rail. A study of the data shows that the lowest recorded load which *started* a fissure in the laboratory was 40,000 lb. However, after a fissure is started it will spread under a load less than that required to start it. From a study of rolling-load test results an admittedly crude estimate is that once a fissure *started* to spread under loads of 40,000 lb. or more, then after 200,000 wheel loads of 30,000 lb. or more rail fracture *might* occur. From the records of wheel-load tests north of Dayton it was concluded that at the worst location tested 3 percent of the wheel loads might be 30,000 lb. or greater. Estimating an average axle load of 10 tons, and remembering that the tonnage passing is that for *two* lines of rail, this would mean the passage of about 65,000,000 tons of traffic before there would be great probability of failure by transverse fissures.

Again the fact that this was a very crude estimate must be kept in mind. Wheel loads of 40,000 lb. and higher were measured on the tracks north of Dayton, and their observed frequency would lead to an estimate of 15,000 such loads under 65,000,000 tons of traffic at the "worst" location studied. This would probably be an ample number of wheel loads to *start* a fissure.

It will be noted in the tabulation that the first fissures to appear in the test rail were those in Heats 50110 and 43118 which failed in service, breaking the block signal circuit, but causing no derailment. These heats were expected to fail first, since their etch test specimens contained more shatter cracks than specimens from any of the other heats in service at that location. The failures occurred after an estimated 73,000,000 tons of traffic had passed over the track. The vertical split head in Heat 50110 was the top rail in Ingot 1 of that heat. It was laid as the first rail leading to the west-passing track at the Needham yards and failed after an estimated traffic of 59,000,000 tons. It is possible, however, that, due to its location, it actually carried more than the estimated tonnage and possibly was subjected to a great many more loads of high magnitude.

The failures in Heats 47248 and 27525 which occurred after only 50,000,000 and 59,000,000 tons, respectively, were in a location about 16 miles from where the wheel-load tests were made and, as noted above, the rails were not put into service until several years later than the others.

Again the caution must be repeated that the estimates for probable life of shatter-cracked rail are very crude indeed, and the actual tonnages carried will often vary widely from those estimates. However, the comparison of estimated and observed tonnage before failure at the Dayton location is interesting.

VI. ROLLING-LOAD TESTS FOR BATTER OF RAILS

By H. R. Thomas and N. J. Alleman

25. Results of Rolling-Load Tests:—Since the presentation of the Fourth Progress Report of the Joint Investigation of Fissures in Railroad Rails,[8] additional samples of end-hardened rails, together with their companion unhardened rails, have been tested in the rolling-load machine. As described last year, batter curves are plotted from the results obtained from the rolling-load tests, and from these curves the amount of batter after a given number of cycles of wheel load may be obtained.

In Fig. 13 there are plotted the values of batter after 1,000,000 cycles of 40,000 lb. wheel load from results obtained on end-hardened and unhardened rails since the last report. For comparison, the results previously reported are included also. This figure indicates the weight of rail, end-hardening method, hardness of head of rail and method of support for the various tests. In Fig. 14 these same batter results have been plotted, using the hardness of the rails as abscissas. The open circles indicate values for unhardened rails, while solid circles indicate end-hardened rails. For ease in comparison, lines have been drawn connecting corresponding points for end-hardened and unhardened rails.

26. Discussion of Results:—While definite conclusions should not be drawn from such a limited number of tests, it appears that a Rockwell hardness of less than, say, C 35 (Brinell 325) cannot be expected to assure a satisfactory reduction in the amount of batter. All of the end-hardening processes appear to be effective in reducing the batter provided a proper hardness is attained.

The depths of the hardened zone produced by the various end-hardening processes used in these tests varied from about ¼ in. to the full depth of the rail head. These rolling-load tests, however, do not give any definite information concerning the depth of the hardened area necessary for satisfactory service. Some of the factors involved in any consideration of the desirable depth of hardened zone are: (1) The depth should be

[8] AREA Proceedings, Vol. 39, page 807, (1938).

Rail Sample No.	Weight of Rail	Mill	Hardening Process No.	Mill or Field Hardening	Method of Support	Rockwell C. Hardness	Batter-in Inches 0 .01 .02 .03 .04
2029-31	131	B	Unhard.	Mill	Rigid	19	
2026H-28H	"	"	1	"	Beam	43	
2040-41	112	C	Unhard.	"	Beam	19	
2040H-41H	"	"	2	"	"	30	
2058-59	131	D	Unhard.	"	Rigid	21	
2058H-59H	"	"	2	"	"	36	
2077-79	131	E	Unhard.	"	Beam	25	
2077H-79H	"	"	2	"	"	36	
2016-16A	131	I	Unhard.	"	Beam	24	
2020-20A	"	"	3	"	"	37	
2090-90A	112	I(m)	Unhard.	"	Rigid	20	
2090H-90AH	"	"	4	"	Beam	45	
2091-91A	131	I	Unhard.	"	Beam	22	
2091H-91AH	"	"	4	"	"	42	
2067-69	112	F	Unhard.	"	Beam	26	
2067H-69H	"	"	5	"	"	39	
2088-89	112	D	Unhard.	"	Rigid	19	
2088H-89H	"	"	6	"	"	31	
2093 93A	131	E	Unhard.	Field	Rigid	18	
2093H-93AH	"	"	7	"	"	28	
2111A-12A	131	B	Unhard.	"	Rigid	23	
2111AH-12AH	"	"	10	"	"	36	
2125 25A	112	F	Unhard.	"	Rigid	22	
2125H-25AH	"	"	11	"	"	44	
2135-36	131	F	Unhard.	"	Rigid	21	
2135H-36H	"	"	12	"	"	36	

Notes Hardness measured on top of head, $\frac{1}{8}$ in. from end.
(M) indicates miter-cut rail ends.

Fig. 13. Batter after 1,000,000 Cycles of 40,000-lb. Wheel Load.

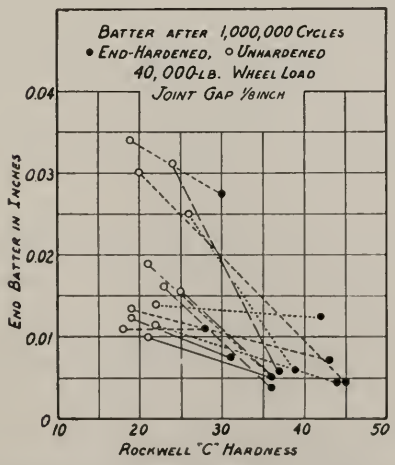


Fig. 14. Relation of Batter to Hardness.

greater than the depth to the point of maximum shearing stress due to the direct action of the wheel load. This ranges from about $\frac{1}{8}$ in. to $\frac{3}{16}$ in., according to wheel load and wheel diameter. (2) The depth should be greater than the amount of wear permitted in the remainder of the rail before it is removed from service. (3) The depth should be greater than the amount of batter permitted before building up rail-ends; this applies to roads where such building-up is the usual practice. In general, the first two items above will require greater depths than this.

Probably the ideal condition for rail ends would be to have the hardness such that the batter at the ends is no greater than the wear on the unhardened part of the rail, and the depth of hardening greater than the allowable wear at points away from the joint. In this case the rail ends can be reconditioned by grinding off any small humps that develop near the joint.

It is hoped that the proposed service tests of end-hardened rail will give further information on the desirable depth of the end-hardened zone.

VII. PROPOSED SERVICE TESTS OF END-HARDENED RAILS

By H. R. Thomas

27. Introduction:—In the fourth progress report of the Joint Investigation of Fissures in Railroad Rails a warning was given[9] that no attempt should be made to evaluate the relative merits of the various end-hardening processes from the results of tests of relatively few joints in the rolling-load machine. Since the effects of speed and of a number of other factors are not present in the rolling-load tests, it was felt that the only logical basis for determining the desirable hardening methods to be used for preventing batter of rail ends was to make service tests covering a number of end-hardening methods, using a sufficient number of rails end-hardened by each process to obtain a satisfactory average.

28. Test Arrangements:—Arrangements have been made through the courtesy of Mr. C. W. Johns, chief engineer, Chesapeake and Ohio Railroad Company, for the installation of end-hardened test rails in the C. & O. track near Carey, Ohio, between Columbus and Toledo. This location is particularly advantageous in that all of the test rails can be placed in one continuous stretch on tangent track, and also because of the heavy traffic of some 37,000,000 tons or more, a year. The grades are light, which will tend toward uniform train speeds over the test rail. The rails will be placed in the north-bound track over which very long trains are hauled by heavy locomotives.

29. Test Program:—At this location there will be laid some 916 test rails. Included among these will be 102 rails with ends hardened by each of 8 hardening methods and, for comparison, 100 rails with ends not hardened. Of the eight end-hardening processes, four will be methods used at the steel mills and four will be field methods. These will include the principal methods now in use, and will cover a range of hardnesses and of depth and length of hardened areas.

It is planned to lay these test rails in the spring as soon as the track is in proper condition, probably some time early in April. During the laying of the rail measurements will be made with the 10-in. AREA batter gage. After resurfacing, these readings will be repeated and measurements will also be made with a 48-in. gage. At this time records will be made for certain joints, using Graham's amplifying recording gage. Hardness measurements will be made on the hardened ends and on the unhardened

[9] AREA Proceedings, Vol. 39, 1938, page 832.

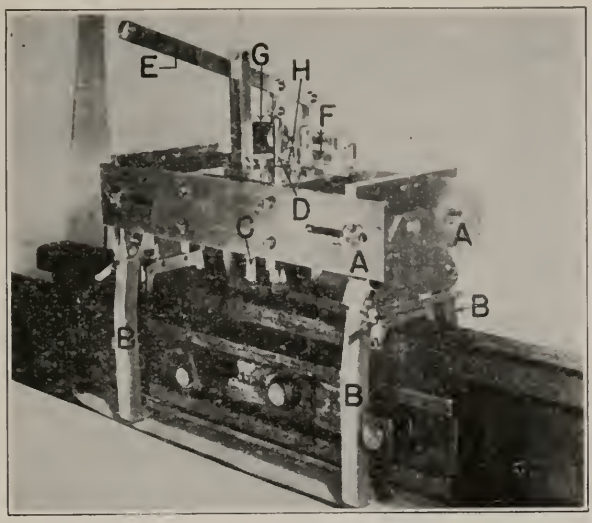


Fig. 15. Portable Brinnell Hardness Tester.

rails, using a new portable Brinell-hardness machine which has recently been built in the University shops.

Measurements of batter with the ten-inch gage will be repeated one month, three months, six months and one year after laying. The interval between measurements after one year will be decided later. At each inspection, joint-gap openings, temperatures, train speeds and any other pertinent information will be recorded. Occasional measurements of rail wear will be made by the use of a profile recorder.

30. Description of Portable Brinell-Hardness Machine:—In planning for the service tests for batter of end-hardened rails it was thought desirable to have a means for making accurate measurements of the Brinell hardnesses of the rails in track. For this purpose a portable Brinell-hardness machine was designed and recently completed in the University shops.

As shown in Fig. 15, the machine consists essentially of a frame A, which can be anchored to the rail by means of the four hooks B. At the center of the frame is an unpacked hydraulic cylinder C at the lower end of which is attached a standard Brinell ball. The standard load of 3,000 kg. is applied by oil pressure forced into the cylinder by the pump-piston D, operated by lever E. Load is measured by the lever system F and the weight B, which balances the pressure exerted by the oil against unpacked piston H. Valve K is used for releasing the load. Means are provided to permit readings to be taken up to ½ in. on each side of the center line of the rail, and the attachment-hooks may be adjusted lengthwise of the frame in order to clear ties or joint bolts. The machine weighs only 28 lb., largely due to the use of a high-strength aluminum alloy in its construction.

VIII. MISCELLANEOUS TESTS

31. Effect of Gagging Rail:—The question has often been asked, "Is a rail damaged by 'gagging' to straighten it, or by cold straightening if kinked in service?" If so, what properties are injuriously affected—such as strength (static or "fatigue"),

ductility or toughness? In connection with the study of the bend test, rail specimens were very severely bent—subjected to what is equivalent to a very severe gagging at mid-span, less severe gagging at the quarter span, and no gagging at all beyond the supports. From several of these specimens test sections about six inches long have been cut off under a load point where fracture had not taken place and beyond the support. Some of the test pieces from under a load point, which have been heavily gagged, were straightened cold in a testing machine, others were left as bent. Specimens have been cut from the "gagged" metal, the gagged and straightened metal, and the ungagged metal (at the ends), and, tensile tests, fatigue tests and impact tests are in progress. It is hoped to gain some idea of the amount of structural damage, if any, caused by a single heavy gagging of rail steel.

32. **Study of Steel from Rails After a Rolling-Load Batter Test:**—The question has arisen how the physical properties of the metal in the hardened end of a rail are affected by the cold work of passing wheel loads. In rolling-load specimens which have been subjected to the batter test there is available a supply of material which has been so cold worked, and the experimental study of strength and toughness of specimens from this material, compared with similar tests from rails with unhardened ends which have been subjected to the rolling-load batter tests, may give valuable information on this subject. Such tests are in progress.

FIRST PROGRESS REPORT—JOINT INVESTIGATION OF CONTINUOUS WELDED RAIL

By Herbert F. Moore

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Howard R. Thomas

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and

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I. INTRODUCTION

Foreword:—In putting out this progress report especial emphasis is laid on the fact that it is a progress report and not a final report. It has been necessary to report tentative values of fatigue strength, drop-test values and bend-test values for continuous welded rail on the basis of very few tests. This necessity in the case of fatigue tests is one faced by all investigators of fatigue properties of full-sized members. It is most strongly urged that these results be regarded as tentative, and if they are so regarded, it is believed that the publication of them at this time will be of value.

1. Beginning of Investigation:—In September 1937 arrangements were completed for a co-operative investigation of continuous welded rail. The investigation is under the joint auspices of the Association of American Railroads and the Engineering Experiment Station, University of Illinois. The Association of American Railroads through the American Railway Engineering Association Committee on Rail appointed the following Advisory committee for the investigation:

J. C. Patterson, Chief Engineer Maintenance of Way, Erie Railroad (Chairman)
G. M. Magee, Research Engineer, Engineering Division, Association of American Railroads
C. E. Morgan, Superintendent Work Equipment and Track Welding, Chicago, Milwaukee, St. Paul & Pacific Railroad
G. R. Smiley, Chief Engineer, Louisville & Nashville Railroad
H. S. Clarke, Engineer Maintenance, Delaware & Hudson Railroad

Mr. Clarke has died since the beginning of the investigation, and the members of the test party of the investigation wish to record here their appreciation of his help in the early testing work of the investigation, and their deep sorrow at his loss. Mr. P. O. Ferris, Engineer of Maintenance of Way, Delaware & Hudson Railroad has been appointed in Mr. Clarke's place.

At the University of Illinois the work was placed under the general direction of Professor H. F. Moore. Close contact is maintained with Professor A. N. Talbot and the Special Committee on Stresses in Railroad Track. One-quarter of the time of Professor H. R. Thomas, engineer of tests, and of Professor R. E. Cramer, metallurgist, is given to this investigation. The assistance of Messrs. S. W. Lyon, J. L. Bisesi, E. C. Bast, and N. J. Alleman is gratefully acknowledged. Acknowledgment is also made of the co-operation of the following representatives of welding companies in preparing specimens and offering constructive criticisms of test methods and form of presentation of results:

Lem Adams, Vice-President, Oxweld Railroad Service Company
C. A. Daley, Maintenance of Way Engineer, Air Reduction Sales Company
J. H. Deppeler, Chief Engineer, Metal & Thermit Corporation
H. C. Drake, Director of Research, Sperry Products, Incorporated

2. General Outline of Work:—Eventually a considerable amount of field study of welded joints will have to be done, and some is in progress already. The general lines of laboratory investigation in progress are:

1. Etch tests of the metal in specimens of welded rail joints made by various processes, to see whether any "flakes," laps, holes, burns, inclusions, cracks, or any other type of defect, have formed during the process of welding and subsequent cooling, and, if so, where these defects are located in the joint.
2. Hardness surveys of the metal in the weld, in the adjacent rail and in the transition zone between weld metal and rail metal.
3. Survey of typical crystalline structure in weld, rail and transition zone by means of the metallographic microscope.
4. Chemical analyses of steel in rail, in weld and in the transition zone.
5. Mechanical tests of specimens cut from weld metal, rail metal, and transition zone. These tests include tension tests, impact tests and fatigue tests.
6. Rolling-load fatigue tests of full-size specimens of welded rail to determine: (a) Whether internal fissures can be developed in welded joints, (b) to determine the fatigue strength in flexure of welded joints, and (c) to determine likelihood of damage to the web of the rail near the weld.
7. Drop tests and bend tests of full-size rail joints.

In planning tests and considering test results two bases of comparison must always be kept in mind: (1) A comparison between the welded joint and the ordinary joint-bar joint as to strength and toughness and wearing qualities, and (2) a comparison between the welded joint and the rail. In comparing the strength and other properties of welded joints with those of ordinary joint-bar joints close contact is maintained with the work of Professor A. N. Talbot's Committee on Stresses in Railroad Track.

3. Types of Welded Joint Studied:—Up to the present time 104 test rails welded by five different processes have been supplied.

Process A. Twelve 112-lb. rails and twelve 131-lb. rails. This process is a gas welding process. The rails were first beveled with a torch and the joint welded by two welders, one on each side of the weld. A special welding rod was used. The base was welded first, starting at the web; next the web was welded from base to head, then the head was welded. When completed the top surface was peened by hammering. It took about one and one-half hours to complete a weld. After the head had cooled to black heat the entire rail was heated with a large acetylene torch to a normalizing temperature (about 1,600 deg. F.) for a distance of about 3½ in. on each side of the weld. Then a strip of sheet metal was placed around the weld and filled with ground magnesia insulating material, covering a distance of about eight inches on each side of the weld. This material allowed the heated head of the rail to cool to about 200 deg. F. in about three hours.

Process B. Twelve 112-lb. rails and twelve 131-lb. rails. This was also a gas welding process. The rail ends were beveled with a cutting torch. The surface of the bevel was ground clear of oxide. One welder made each joint. First the web of the rail was welded, starting from the junction of web and base and welding up to the head. The second step was to weld the base on both sides from the web out. The head was welded last. The weld metal was deposited in layers across the extent of the head and peened several times with the hammer during welding. The weld took about three hours to complete.

After the welding was complete, a special furnace was put around the weld and the weld was heated to about 1,200 deg. F.—a stress-relieving treatment. The holes in the furnaces used for burners were then covered and the rail allowed to cool in the furnace. It required approximately three hours for the rail to cool to 300 deg. F.

Process C. Twelve 112-lb. and twelve 131-lb. rails. This was the Thermit process using the intense heat generated by the transformation of aluminum to aluminum oxide. The welding of the rails by this process consists of three main steps: (1) The preparation of the rails for welding—including cutting of the gap, end-facing and alinement; (2) the actual welding of the rail—which includes preheating, pouring of the molten products of the reaction into the molds, and pressing together the rails in order to effect the pressure weld; and (3) the finishing operation—knocking off the catch basins and steel nubs on the sides of the head, post-heating to relieve strain, grinding and finishing the gage and tread surfaces.

The extensive details of this process and further details of the other processes are not given here in this summary but are on file at the office of the investigation at the University of Illinois.

Process D. Electric Flash Pressure Butt Welds. Twelve 131-lb. rails. The detailed description of this process involving, as it does, very elaborate equipment and the welding together of as much as 1,400 ft. of rail before placing it in the track will not be given here. A quite complete description may be found in the Railway Age for September 4, 1937, page 300.

Process E. Gas-heated Pressure Butt Welds. Twelve 112-lb. rails. The rail ends to be joined were ground square. A special oil-pressure cylinder was used to force the rail ends together under longitudinal pressure. While pressure was being applied the metal on both sides of the joint was heated by a large number of small oxy-acetylene flames, completely surrounding the rail joint. These flames were on a movable frame which oscillated back and forth along the rail through about 1½ in. on each side of the abutting rail ends. As the rail steel softened under the heat of the gas flames, the steady pressure of the oil-pressure cylinder forced the rail ends together about ⅞ in., forming an upset bead of deformed metal at the joint. After the flames had been shut off, and the rails had cooled below the critical temperature of the rail steel, they were reheated in another oxy-acetylene heating rig slightly above the critical temperature to refine the grain of the joint metal and relieve internal stresses in the steel.

II. ETCH TESTS, METALLOGRAPHIC TESTS AND HARDNESS SURVEYS

By R. E. Cramer, assisted by E. C. Bast

4. Etch Tests of Metal at Welded Joint:—Fig. 1 shows typical etch test results for test joints welded by the five processes studied. The etch tests shown in Fig. 1 were on horizontal slices from rail heads, approximately $\frac{3}{16}$ in. below the tread. The slices were rough polished and then etched in a 50 percent solution of hot hydrochloric acid for 20 to 40 min. In Fig. 1 (a) and (b) the regularly spaced dots are the marks of the Rockwell "C" diamond cone, used in the hardness surveys.

Evaluating etch-test results is very difficult. Evidences of inclusions, laps, bending of the "fiber" of the metal and some crack-like markings are shown. How much damage these do is rather uncertain, although actual cracks may do very considerable structural damage by acting as nuclei for the spread of fissures, or other fatigue cracks. Obviously the macro-structure of the steel in and near the weld has been changed from that in the rail itself. The macro-structure of the joint metal is further discussed after the results of tests of joints to fracture under repeated wheel loads have been presented.

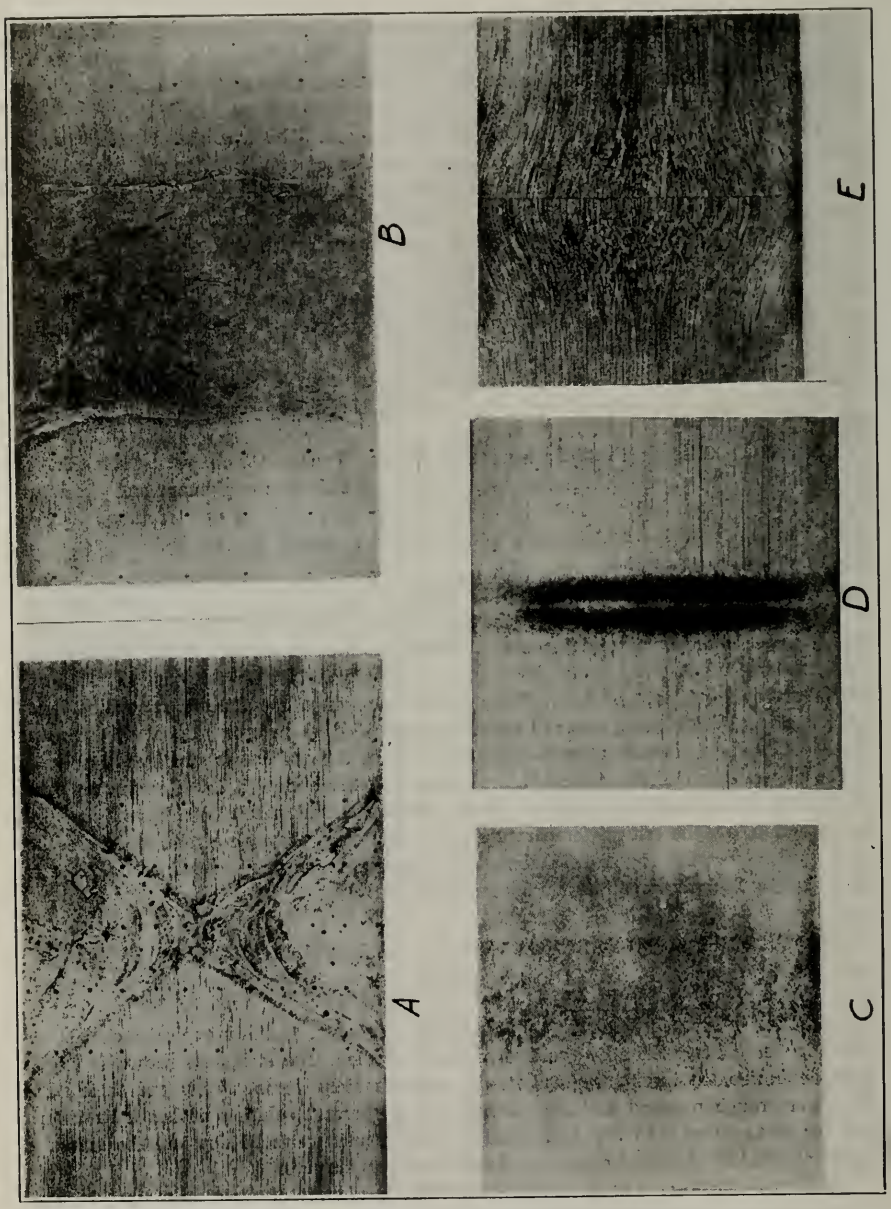


Fig. 1. Horizontal Etched Sections of Welds $\frac{3}{16}$ in. Below the Tread.

Etched with hot hydrochloric acid. Approx. 0.6 natural size.
A. Fusion gas weld, Specimen W 8, Process A.
B. Fusion gas weld, Specimen W 101, Process B.
C. Thermit weld, Specimen W 252, Process C.
D. Electric flash pressure weld, Specimen W 303, Process D.
E. Gas-heated pressure weld, Specimen W 406, Process E.
Note, the regularly spaced dots on A and B are the marks of the Rockwell "C" diamond cone point used in the hardness surveys.

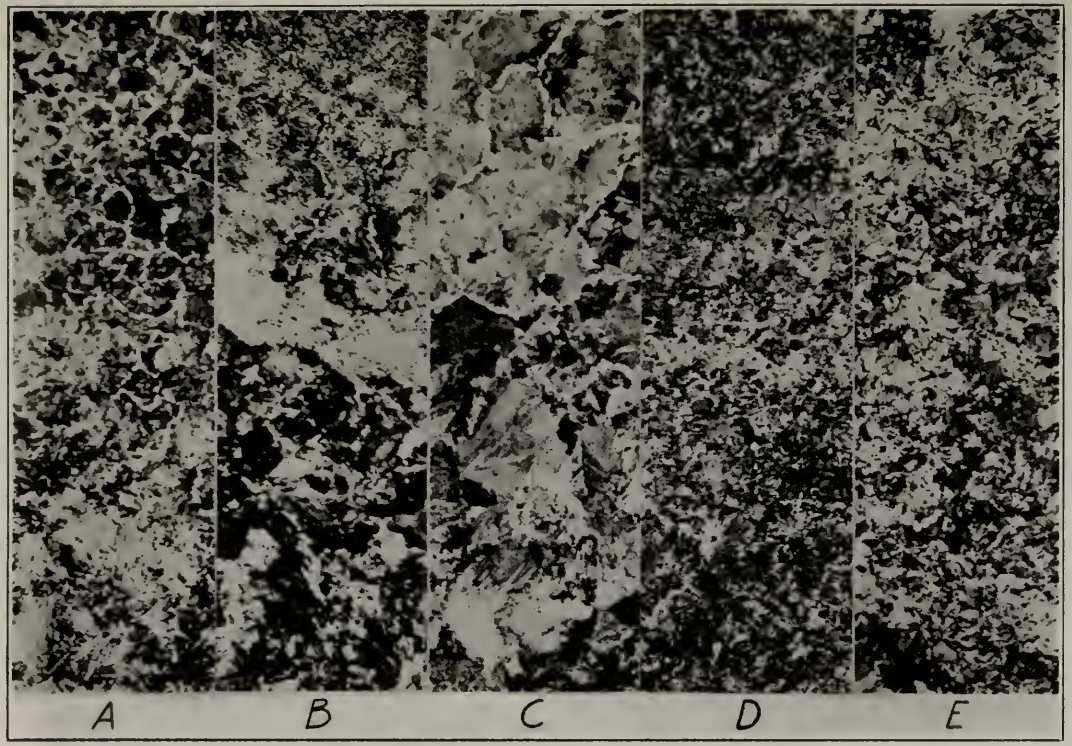
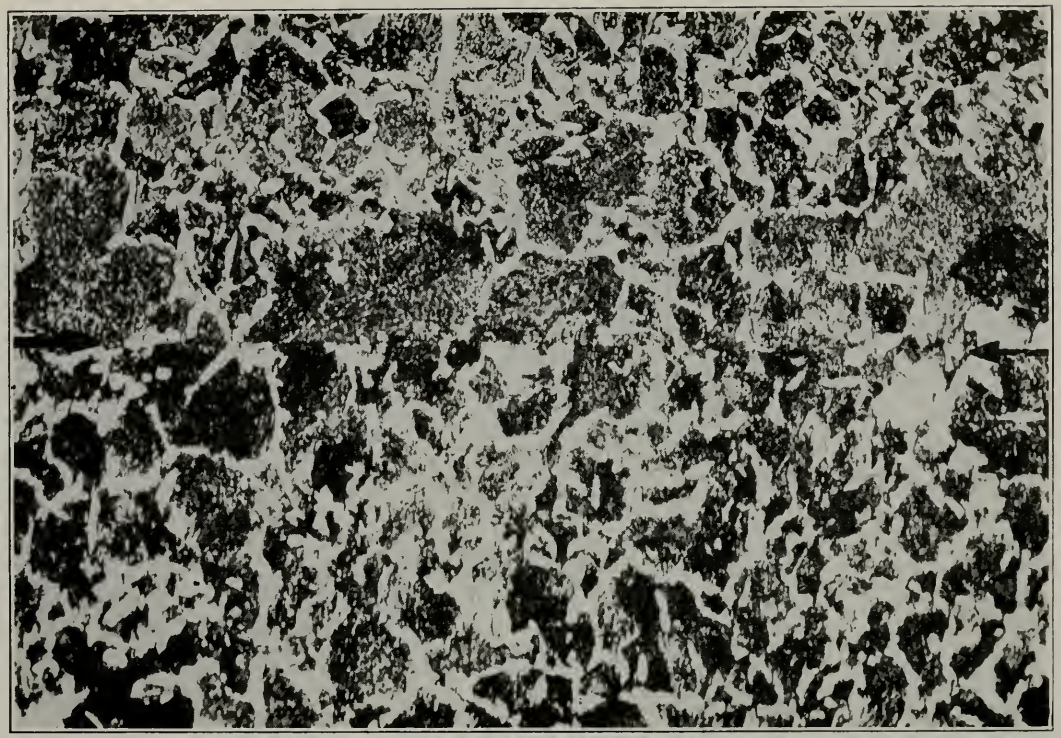


Fig. 2. Micrographs of Crystalline Structure at Junction of Weld Metal and Rail Steel.

Magnification 56 X.
Etch 2 percent nital.
A. Fusion gas weld, Process A.
B. Fusion gas weld, Process B.
C. Thermit weld, Process C.
D. Electric flash pressure weld, Process D.
E. Gas-heated pressure weld, Process E.

Junction Line



Junction Line

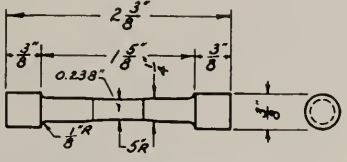
Fig. 3. Micrograph Showing Junction Line Outlined by Break in Crystalline Structure of Steel in Butt Weld. Process E.

Magnification 320 X.
Etch 2 percent nital.

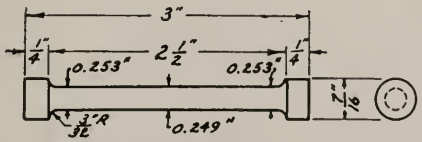
One method of locating the junction line of butt welded rails is to examine the surface of the rails, especially if it is decarburized as was the case in the joint shown above. In this decarburized metal the pattern of the ferrite network in one rail does not match that of the other, thus making the junction line quite distinct.

5. Micrographs of Steel in Welded Joints:—Fig. 2 shows micrographs of the metal at the weld and on each side of it for the five types of welded joints tested. It will be noted that the specimens for Processes A, B and C show more ferrite and larger grain sizes than do the specimens for Processes D and E. Fig. 3 shows a method for locating the junction line of butt-welded rails by examining the decarburized surface of the rails. In this metal the ferrite and pearlite grains of the two rails do not "match" and thus the junction line is made quite distinct.

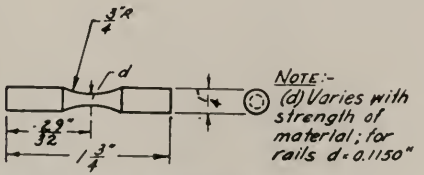
6. Hardness Surveys of Welded Joints:—The Rockwell "C" hardness test was selected as the most suitable for hardness surveys of areas of rail steel, weld metal, and the fairly well-defined "heat affected area" adjacent to the weld metal. This test measures the net penetration of a diamond cone point under a load of 150 kg. after an initial load of 10 kg. has been applied. Hardness tests were made over the area of the weld region cut by various planes, horizontal and vertical. Indentations were made ½ in. apart along the rail, and, usually, ¼ in. apart across the rail. The results on a horizontal plane $\frac{3}{16}$ in. below the tread of the rail are given in Table 1. These results give some idea of the relative hardness of rail, heat-affected zone and weld metal, and also some idea of the "scatter" of hardness values. With the small indentation made by the Rockwell "C" diamond brale (cone point) more localized spots of hard or soft metal are detected than with the relatively large indentation of a Brinell ball. It is rather doubtful



TENSION SPECIMEN



IMPACT TENSION SPECIMEN



HIGH SPEED FATIGUE SPECIMEN

Fig. 4. Types of Specimens for Mechanical Tests of Welded Joints.

TABLE 1

HARDNESS SURVEYS OF WELDED RAIL JOINTS

Rockwell "C" numbers along horizontal section $\frac{3}{16}$ in. below tread of rail

Type of Joint	*Weight of Rail lb. per yd.*	*Rockwell "C" Numbers*								
		Rail			*Heat affected zone*			*Weld metal or junction line*		
		Min.	*Av.*	*Max.*	*Min.*	*Av.*	*Max.*	*Min.*	*Av.*	*Max.*
Fusion weld A (gas)	112	21	22	24	13	21	25	13	22	30
Fusion weld B (gas)	131	22	23	24	17	26	29	28	31	37
Thermit weld C	112	21	23	24	19	24	26	16	22	26
Thermit weld C	131	20	22	24	23	27	29	10	25	28
Electric flash butt weld D	131	21	23	24	27	28	30	27	30	32
Gas heated pressure weld E	112	21	23	24	16	20	24	17	25	28

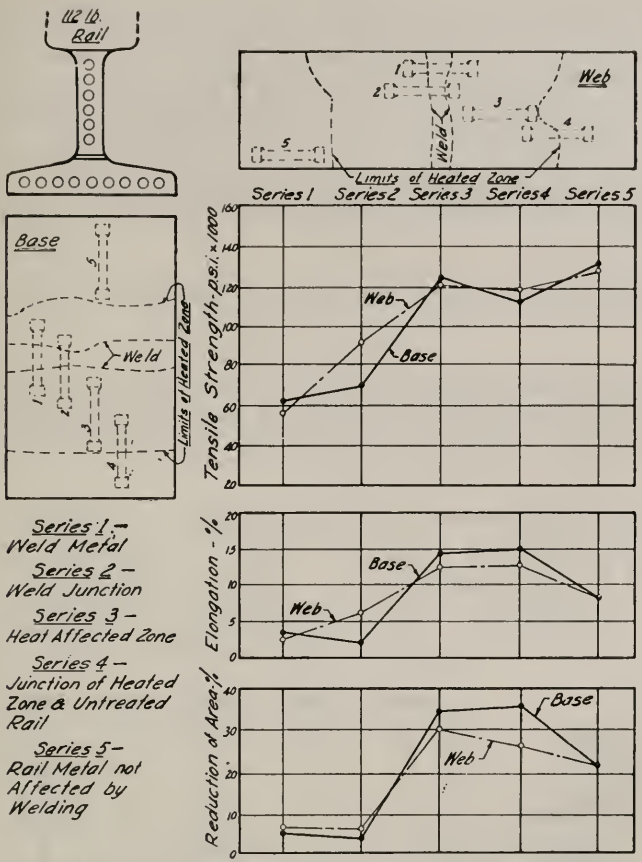

112 lb. Rail
Web
Weld
Limits of Heated Zone
Series 1 Series 2 Series 3 Series 4 Series 5
Base
Limits of Heated Zone
Tensile Strength, p.s.i. x 1000
Elongation - %
Reduction of Area - %
Series 1 — Weld Metal
Series 2 — Weld Junction
Series 3 — Heat Affected Zone
Series 4 — Junction of Heated Zone & Untreated Rail
Series 5 — Rail Metal not Affected by Welding

Fig. 5. Welded Joint No. W-12, Process A—Tension Test Results.

whether the low Rockwell numbers reported are as significant as an index of general hardness of the metal as Brinell readings, but Rockwell readings are more sensitive to localized variation of hardness in the metal. It will be noted that for Fusion gas weld B the weld metal was distinctly harder than the rail steel. This is probably due to the welding rod used. In general, it would seem to be of advantage to have the weld about as hard as the rail steel, to even up the wear along the track.

7. Chemical Analyses of Rail Steel and of Welding Rods:—The following analyses were reported for rail steel and welding rods.

Rail steel for joints made by Processes A, B, C and D, reported by Robert W. Hunt Company;

131-lb. rail, Carbon 0.71 percent; Manganese 0.81 percent; Phosphorus 0.023 percent; Sulphur 0.037 percent; Silicon 0.15 percent.

112-lb. rail, Carbon 0.70 percent; Manganese 0.76 percent; Phosphorus 0.020 percent; Sulphur 0.024 percent; Silicon 0.19 percent.

Rail steel for joints made by Process E, reported by firm making the test joints.

112-lb. rail, Carbon 0.73 percent; Manganese 0.80 percent; Phosphorus 0.020 percent; Sulphur 0.022 percent; Silicon 0.20 percent.

Welding rods used in Process A and rods used in Process B, analyses reported by firms making the test joints.

Welding rod for Process A, Carbon 0.45–0.50 percent; Manganese 1.00 percent; Silicon 0.45 percent; Chromium 1.00 percent.

Welding rod for Process B, Carbon 0.20–0.40 percent; Manganese 0.85–1.15 percent; Phosphorus 0.035 percent; Sulphur 0.04 percent; Silicon 0.15 percent; Chromium 0.90–1.25 percent; Vanadium 0.10–0.30 percent.

Approximate analysis of weld metal for Process C, Carbon 0.41 percent; Manganese 0.74 percent; Phosphorus 0.036 percent; Sulphur 0.058 percent; Silicon 0.044 percent, reported in Railway Engineering and Maintenance, June 1936, p. 352–356.

III. MECHANICAL TESTS OF SPECIMENS FROM WELDED RAIL JOINTS

By S. W. Lyon

8. Strength, Ductility and Toughness Tests of Specimens from Welds:— Specimens for the usual mechanical tests were cut from weld metal, from heat-affected zone metal and from unaffected rail steel for each type of joint furnished for testing. Tension tests, impact-tension tests, and fatigue tests were made. The specimens used are

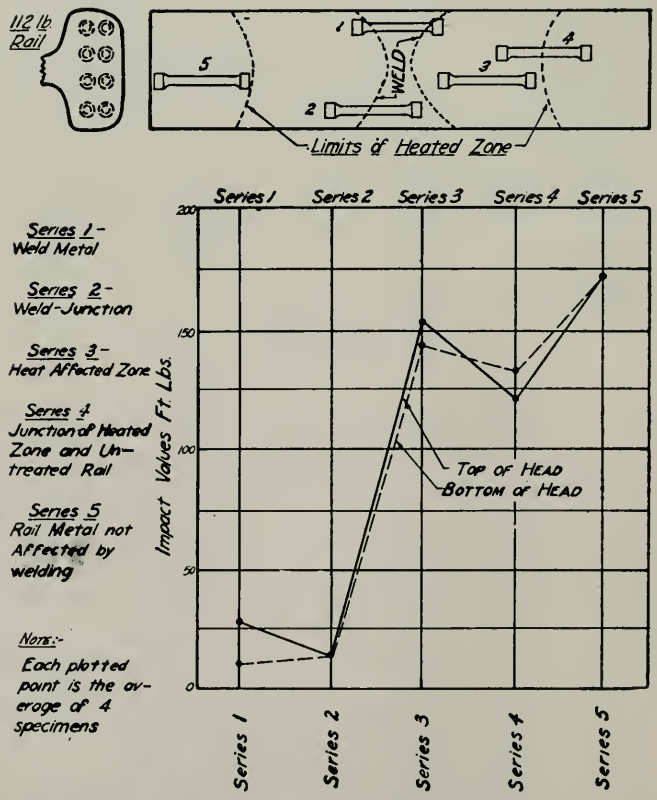


Fig. 6. Welded Joint No. W-12, Gas Welding Process A—Impact Tension Results.

shown in Fig. 4. Tension tests were made in an Olsen screw-power testing machine using Robertson shackles to hold the specimens; impact-tension tests were made in a Charpy impact machine, fitted with a Lyon tension attachment, and fatigue tests were made in small rotating-cantilever machines which subjected the specimen to a complete reversal of flexural stress during a cycle of stress (one revolution of the machine).

Figures 5, 6 and 7 show graphically typical results for tension, tension-impact, and fatigue tests. As will be noted from these figures, specimens were cut from various portions of the welded joint and from the rail steel which is unaffected by the welding treatment. There have been made approximately 550 tension tests, 520 tension-impact tests, and 1,050 fatigue tests, a total of approximately 2,120 specimens tested. Table 2 summarizes the results of these tests. Table 2 is divided into two parts, in one of which (a) the actual test values are tabulated, and in the other of which (b) the values are tabulated in terms of percentage of the figures obtained from the rail steel.

9. Conclusions From the Tests of Specimens:—These tests of specimens cut from welded joints give an indication of the variation of strength of material in different parts of the joint. They do not give any indication on the effect of imperfections such as laps, blow holes, small cracks, inclusions, and sharp changes of outline upon the

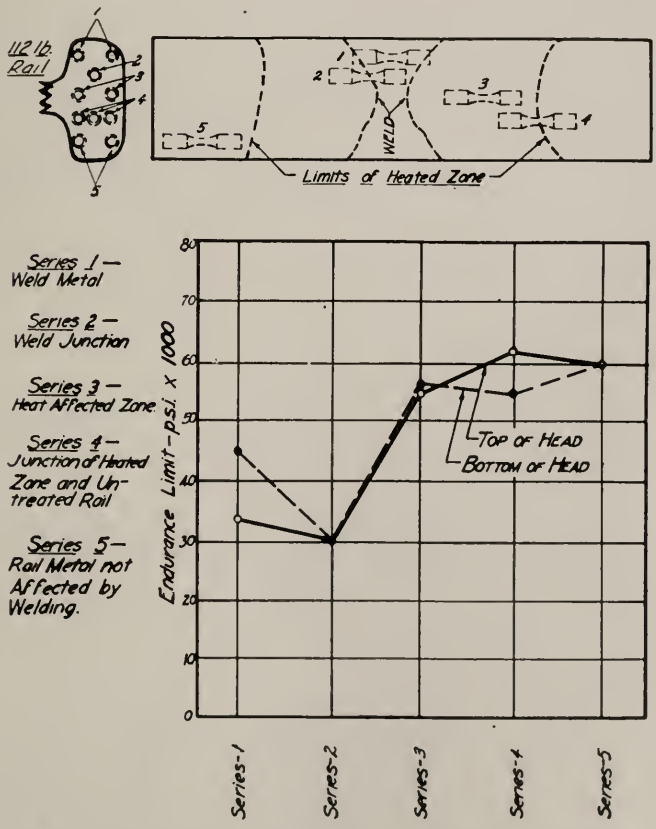


Fig. 7. Welded Joint No. W-15, Process A—Fatigue Test Results.

TABLE 2

TEST RESULTS FOR SPECIMENS CUT FROM WELDED RAIL JOINTS

The values given for rail steel are the average values for the specimens cut from a location in the joint specimen outside the heat-affected zone of metal. The values given for weld metal are the lowest values observed along the length of the weld and in its immediate vicinity. Most of these values are for weld metal, but a few are for the metal at the junction of weld and rail steel.

Part (a) of this table gives the results in terms of the units commonly used in reporting test results, lb. per sq. in., percent and ft.-lb. Part (b) gives the values in terms of percentage of the corresponding values obtained for rail steel.

(a)

Description of Process	Weight of Rail lb. per yd.	Tensile Strength 1,000 lb. per sq. in.			Reduction of Area percent			Impact Tension ft.-lb.			Endurance Limit-1,000 lb. per sq. in.		
		Head	Web	Base	Head	Web	Base	Head	Wab	Base	Head	Web	Base
Rail	112	131	127	133	20	21	22	170	167	167	60	59	62
	131	130	132	134	19	17	21	126	141	147	62	60	60
A—Gas fusion	112	97	57	62	6	7	4	14	6	24	30	35	33
B—Gas fusion	131	105	72	85	2	3	2	5	11	8	55	50	44
C—Thermit	112	113	106	122	4	12	8	28	50	9	29	44	45
	131	113	101	100	4	8	2	37	52	15	34	46	44
D—Electric flash	131	126	131	133	4	6	14	160	85	112	54	44	54
E—Gas pressure	Rail* 112	135	136	139	18	19	21	134	145	141	61	62	62
	Weld 112	122	122	124	16	21	17	92	107	108	48	47	54

(b)

Description of Process	Weight of Rail lb. per yd.	Tensile Strength			Reduction of Area percent			Impact Tension Values			Endurance Limit		
		Head	Web	Base	Head	Web	Base	Head	Web	Base	Head	Web	Base
Rail	112	100	100	100	100	100	100	100	100	100	100	100	100
	131	100	100	100	100	100	100	100	100	100	100	100	100
A—Gas fusion	112	74	45	47	30	33	18	8	4	14	50	59	53
B—Gas fusion	131	81	55	63	11	18	10	4	8	5	89	83	73
C—Thermit	112	86	84	92	20	57	36	16	30	5	48	75	73
	131	87	77	75	21	47	10	29	37	10	55	77	73
D—Electric flash	131	97	99	99	21	35	67	127	60	76	87	73	90
E *—Gas pressure	112	90	90	89	89	110	81	69	74	77	79	76	87

* Rail for Process E not the same as for other processes. Percentage strength for Process E welds computed on basis of rail used for Process E joints.

fatigue strength of a joint as a whole. For judging this effect, the rolling-load tests, which are discussed in the next section, seem distinctly more significant.

However, the tests of these specimens do indicate for all the welded joints a rather wide variation in the quality of material in the joint as welded. None of the material in the welded joint reaches 100 percent of the values for the rail steel with the exception of the impact-tension values for steel from the head of the rail joints welded by Process D, and the reduction of area values for the web of the rail joints welded by Process E. The tensile strength for head, web and base of joints welded by Process D very nearly reached the tensile strength of the rail steel.

IV. TESTS OF WELDED JOINTS UNDER REPEATED WHEEL LOAD

By H. F. Moore, H. R. Thomas and N. J. Alleman

10. Rolling-Load Tests of Welded Joints:—The testing machine used for rolling-load tests of welded rail joints is similar to those used in the Investigation of Fissures in Railroad Rails except that the stroke of the machine is 12 in. instead of 7 in. Fig. 8 (a) shows this machine with a welded specimen after fracture.

The specimen to be tested is placed as shown in Fig. 8 (b). The moment arm at the weld is ten inches and at the weld the bending moment (inch-pounds) is ten times the wheel load.

The following routine has been used in the test: A specimen was put in the machine under a load of 75,000 lb. If the specimen broke before 2,000,000 cycles had been reached a second specimen was put in under a lower wheel load, usually a load of 60,000 lb. If this one broke, a specimen was put in at a still lower load, and the test continued to fracture or to 2,000,000 cycles of load.

The selection of 2,000,000 cycles as the limiting number of cycles for the rolling-load test was based on the following line of reasoning. During the passage of 300,000,000 tons of traffic, a location at any point in the rail would be subjected to approximately 30,000,000 wheel loads, allowing 5 tons as the average wheel load and remembering that the total tonnage is divided between the two rails. From the reports of the Investigation of Fissures in Railroad Rails it may be seen that, judged by records of about one-half a million wheel loads at four characteristic locations, about one wheel load out of one thousand has a magnitude of 40,000 lb. or greater. In rolling-load tests of rail, 40,000 lb. was the lowest wheel load which developed a fissure. Recent experiments at the University of Illinois by Dr. R. N. Arnold* indicate that, owing to inertia effects of the rails, this ratio of one in one thousand might be increased considerably, possibly to a point where one wheel load out of 300 may be expected to reach the value of 40,000 lb. or greater. This would mean that when 300,000,000 tons of traffic had passed over a location—a fair length of service for rail—about 100,000 wheel loads of 40,000 lb. or greater might be developed. Now in fatigue tests in the laboratory it is desirable to make tests under a much greater number of cycles of stress than will probably occur in practice. The reason for this is that above the fatigue limit a small increase in stress causes a great shortening of life. It is well then to make tests to ten times the number of cycles of stress expected in service. In these rolling-load tests the limiting number of cycles chosen was 2,000,000—twenty times the expected number of cycles of the load of 40,000 lb. which may be expected after 300,000,000 tons of traffic has passed over the track.

This maximum number of cycles, 2,000,000, is the same as that used by Professor W. M. Wilson in his studies in fatigue in structural members. The identity of these two figures for number of cycles is an interesting coincidence, nothing more.

* Proc., (British) Inst. Mech. Engr's., Vol. 137, p. 217 (1937).

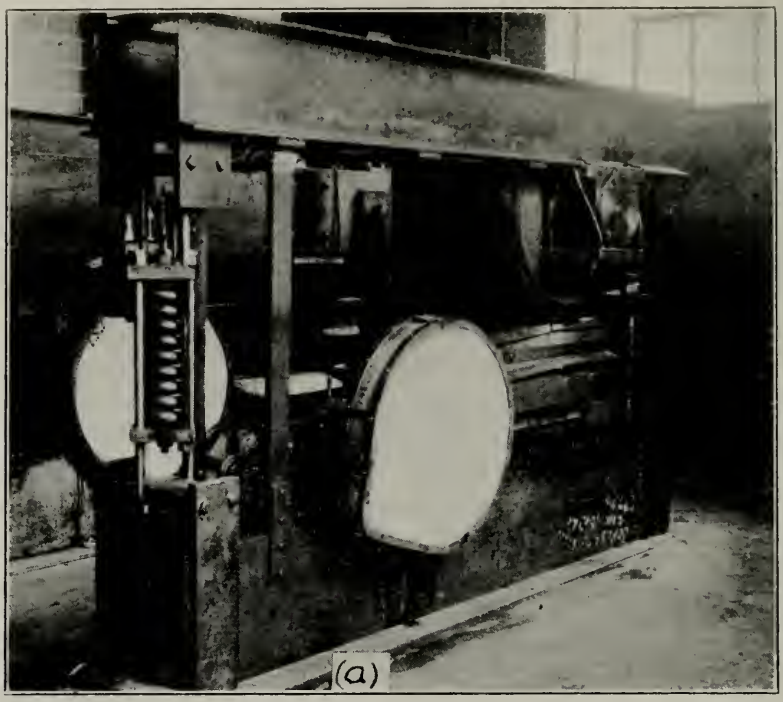


Fig. 8. Rolling-Load Testing Machine for Tests Under Repeated Wheel Load.
(a) General view of machine. Stroke 12 in., speed 60 r.p.m. Note fractured specimen.
(b) Wheel positions on specimen at ends of stroke. During a stroke the bending moment at the weld ranges from zero to ten times the wheel load.

11. Stresses Developed in Rolling-Load Tests:—Failure of a rail or a welded rail joint under repeated wheel loads may arise from several causes. Failure may take place as the result of repeated flexural stresses, and in this case it is usually the tensile stress that causes failure. Failure may take place due to repeated shearing stress in the web of the rail, and this depends upon wheel load rather than bending moment. Failure may take place by the development of internal fissures starting at minute imperfections and caused by the heavy stresses directly under the wheel load. All three of these causes of failure have occurred in the tests of welded joints so far carried out and Fig. 10 shows all three types of fracture.

The shearing stresses in the web and the flexural stresses in the head were computed by the common formulas of mechanics of materials. Their distribution is shown in Fig. 9 for a wheel load of 75,000 lb. on a 131-lb. rail and for a 112-lb. rail.

The specimen is so placed in the rolling-load machine that the head of the specimen is subjected directly to wheel load, and, during a cycle of load, to tensile stress. This is probably a somewhat more severe condition than is met with in rails in track where the compressive stresses are larger than the tensile stresses, although as the train moves over the track there occurs a *partial* reversal of stress in the rail. The maximum flexural stress in the rolling-load test occurs when the wheel is 10 in. from the center line of the welded joint. The maximum wheel load at the weld occurs when the wheel is directly over the joint and the flexural stress is therefore zero. The shearing stresses in the web near the weld remain approximately constant throughout 10 in. of the 12-in. stroke. This arrangement of stress was chosen, not with the idea of reproducing conditions in service pre-

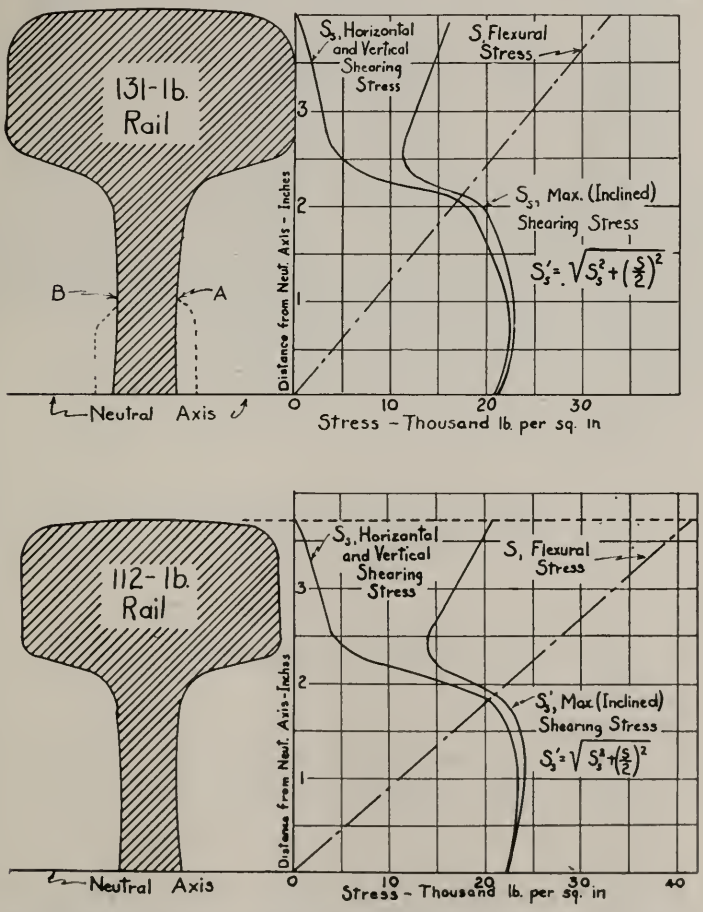

131-lb. Rail
S_s, Horizontal and Vertical Shearing Stress
S Flexural Stress
S_s, Max. (Inclined) Shearing Stress
$S_s' = \sqrt{S_s^2 + \left(\frac{S}{2}\right)^2}$
B
A
Neutral Axis
Distance from Neut. Axis - Inches
Stress - Thousand lb. per sq. in
112-lb. Rail
S_s, Horizontal and Vertical Shearing Stress
S, Flexural Stress
S_s', Max (Inclined) Shearing Stress
$S_s' = \sqrt{S_s^2 + \left(\frac{S}{2}\right)^2}$
Neutral Axis
Distance from Neut. Axis - Inches
Stress - Thousand lb. per sq. in

Fig. 9. Shearing and Flexural Stresses in Test Rail Joint under 75,000 lb. Wheel Load (750,000 In.-Lb. Bending Moment in Rolling-Load Test).

TABLE 3

RESULTS OF ROLLING-LOAD FATIGUE TESTS OF SPECIMENS OF WELDED RAIL

Welding Process	*Specimen No.*	*Weight of Rail lb. per yd.*	*Wheel Load lb.*	*Maximum Flexural Stress* (S)*	*Maximum Shearing Stress* (S_s)*	*Cycles for Fracture*	*Manner of Failure and Remarks*
				lb. per sq. in.			
Rail without weld	NW–406	112	75,000	49,900	24,800	511,200	Fatigue crack corner of head, edge of cold-rolled path.
	NW–410	112	65,000	43,300	21,500	1,650,900	Fatigue crack corner of head, edge of cold-rolled path.
	NW–408	112	60,000	40,000	19,900	2,038,800	Did NOT fracture.
Gas weld fusion Process A	W– 17	112	75,000	41,600	24,400	67,900	Transverse fissure in head.
	W– 13	112	60,000	33,300	19,500	107,300	Transverse fissure in head.
	W– 2	112	40,000	22,200	13,000	1,261,300	Compound fissure in head.
Gas weld fusion Process B	W–109	131	75,000	33,100	23,000	59,500	Horizontal fissure and failure at junction head and web.
	W–110	131	60,000	26,500	18,400	190,800	Transverse fissure in head.
	W–106	131	40,000	17,700	12,300	532,800	Failure started in weld at lap at junction head and web.
Thermit weld Process C	W–256	112	75,000	41,600	24,400	307,400	Transverse fissure in head. Previously tested for 2,000,000 cycles of 40,000-lb. wheel load without fracture.
	W–261	112	60,000	33,300	19,500	275,000	Fatigue crack corner of head, edge of cold-rolled path.
	W–257	112	50,000	27,800	16,200	1,004,100	Fissure near tread, apparently burnt metal.
	W–256	112	40,000	22,200	13,000	2,002,900	Did NOT fracture.
	W–205	131	75,000	33,100	23,000	582,900	Transverse fissure in head.
	W–211	131	60,000	26,500	18,400	1,484,700	Transverse fissure in head and also failure at junction head and web.
	W–208	131	55,000	24,300	16,900	1,378,100	Failed in web at "collar" of weld.
Electric flash pressure weld Process D	W–308	131	75,000	33,100	23,000	1,769,400	Failed in web where metal has been ground off so as to form a re-entrant angle. See "A" Fig. 10 and (b) Fig. 12.
	W–305	131	75,000	33,100	23,000	942,300	Fatigue failure in web outside of weld, starting at a stamped letter on web. See Fig. 12 (a).
	W–309	131	75,000	33,100	23,000	2,001,600	Did NOT fracture.
Gas pressure weld Process E	W–403	112	75,000	41,600	24,400	650,600	Fatigue crack at corner of head, edge of cold-rolled path, also crack started at a stamped letter on web.
	W–402	112	60,000	33,300	19,500	1,269,900	Fatigue crack at side of head.
	W–401	112	55,000	30,600	17,900	2,046,500	Did NOT fracture.

* For specimens with welds Fig. 10 shows variation from tread of rail to neutral axis of: (1) Flexural stress, (2) horizontal and vertical shearing stress and (3) maximum shearing stress (inclined). For specimens of rail without weld the values of S for specimens with weld are multiplied by 1.2, since the maximum-moment arm to the center of the weld is 10 in., while the maximum moment arm for specimen without weld is 12 in.

cisely, but with the idea of producing measurable stresses of the same kind which occur in practice and studying their effect.

12. Results of Rolling-Load Tests to Date:—Table 3 gives the results of rolling-load tests so far run. It will be noted that the two gas weld joints failed to withstand 2,000,000 cycles of load of even 40,000 lb. The Thermit 112-lb. specimen under

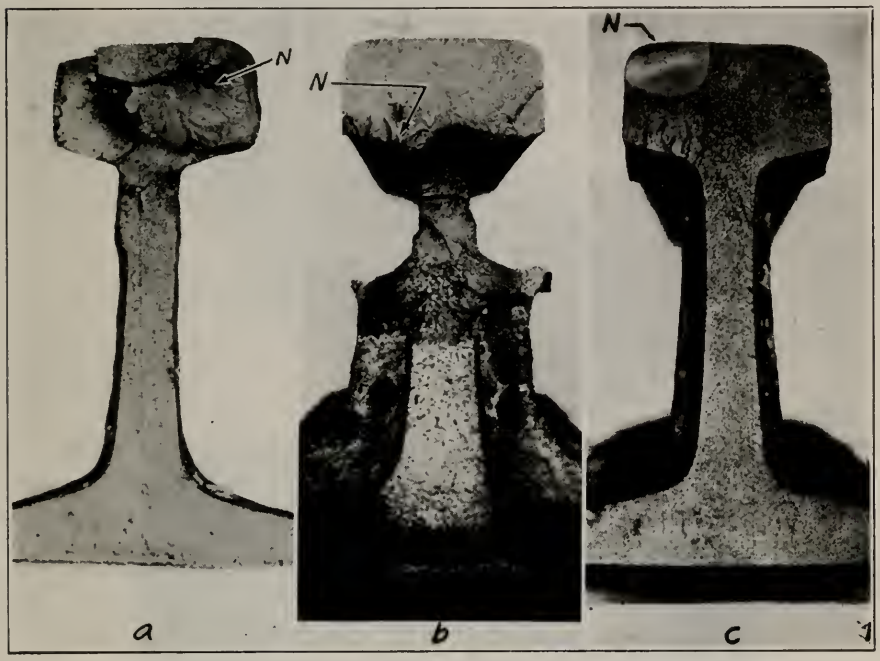


Fig. 10. Typical Fractures of Welded Joint Specimens in Rolling-Load Test.

a. Transverse fissure in head. Fissure started at N, and fracture occurred after 1,216,300 cycles of a 40,000-lb. wheel load.
b. Fissure started at N near junction of web and head, just outside the weld. Fracture occurred after 1,378,100 cycles of a 55,000-lb. wheel load.
c. "Fatigue" failure by spreading crack starting at N near corner of tread of rail. Crack started in coarse transverse grinding marks left on head of rail. Failure occurred after 650,600 cycles of a 75,000-lb. wheel load.

40,000-lb. load did withstand 2,000,000 cycles, but the specimens under 50,000 lb., 60,000 lb. and 75,000 lb. did not. The test of the Thermit 112-lb. welded joint under 75,000-lb. wheel load is of interest in that it withstood more cycles of load than did the joint under 60,000 lb. This may be due to the fact that it had previously been subjected to 2,000,000 cycles of a 40,000-lb. load without fracture. This seems to indicate that welded joints may be strengthened by being subjected to many cycles of stress below the fatigue limit of the original material. This phenomenon of strengthening of metals by repeated understress has been known for several years, and repeated understress is just what rail joints receive in service—together with a rather rare overstress.

Three electric flash welded joints have so far been put into the machine and all tested under 75,000-lb. wheel load. In the first one the excess metal was ground off over about as much of the perimeter of cross-section as is common in practice. The shape of metal left is shown at "A" in Fig. 9. This left a sharp re-entrant corner across the line

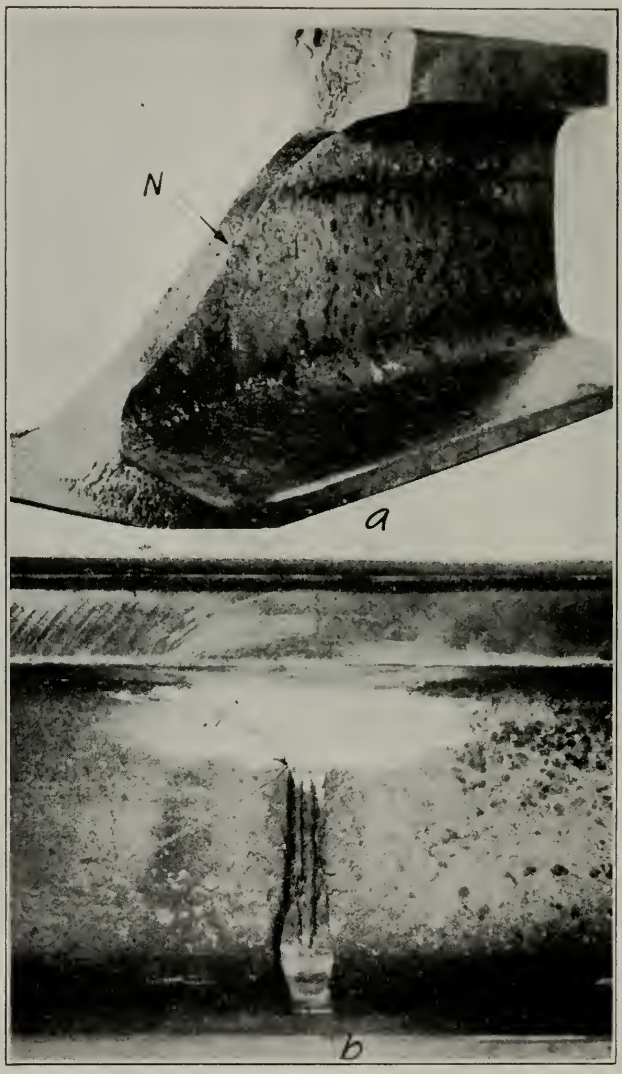


Fig. 11. Welded Joint Fractures Starting at "Stress Raisers" in the Web.

a. Fracture started at N on a line tangent to the curved part of the letter "C" which was stamped on the web of the rail. Fracture was outside the weld zone.

b. Fracture started at N where there was a sharp re-entrant angle (shown at A in upper half of Fig. 9) left after grinding off excess weld metal. After this rail failed the excess metal was ground off as shown at B in Fig. 9, avoiding a sharp re-entrant angle.

of vertical shearing stress,—a "stress raiser." The second specimen had the metal ground off as shown at "B" in Fig. 9, in an attempt to avoid this stress raiser. The first specimen failed by a crack starting at point "A", and this crack is shown in Fig. 11 (b).

The second specimen failed after 942,300 cycles of a 75,000-lb. wheel load. The failure was not through the weld, not in the heat-affected metal, but it started from a stamped letter on the web of the rail. (See Fig. 11 (a)).

The third specimen, which had no stamped letter on the web of the test specimen and in which the excess weld metal had been ground off so as to avoid a sharp re-entrant corner, ran out for 2,000,000 cycles of a 75,000-lb. wheel load without failure.

Three specimens of welded joints in 112-lb. rail have been tested in the rolling-load machine in which specimens the weld was a pressure butt weld with the heat furnished by gas, (Process E). In these welds the temperature used was less than in the fusion processes A and B. Under 75,000-lb. wheel load 650,600 cycles were required to produce

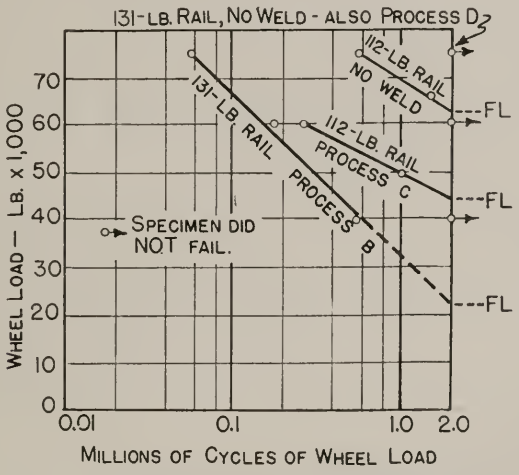


Fig. 12. Typical Load-Cycle Diagrams for Estimating the Endurance Limit Under 2,000,000 Cycles of Wheel Load on Specimens of Continuous Welded Rail.

FL denotes the endurance (fatigue) limit.

fracture. The fracture started at the edge of the path cold rolled on the tread by the wheel, but at the same time another spreading fracture had started at a stamped letter on the web. The second specimen fractured after 1,269,900 cycles of a 60,000-lb. wheel load. The fracture started in the fillet between head and web. The third specimen withstood without fracture 2,046,500 cycles of a 55,000-lb. wheel load.

13. **Tentative Endurance Limits for Welded Joint Specimens:**—As has been previously noted, it seems suitable to determine endurance limits of welded rail joints for 2,000,000 cycles of wheel load. Fig. 12 shows how this limit was determined for specimens of 112-lb. rail without welds, for 112-lb. rail with Thermit welds, and for specimens of 131-lb. rail gas-welded by Process B. The endurance limits for the other types of weld were determined in a similar manner. The results of three or more tests of each type of joint were plotted on load-cycle diagrams, in which wheel load was plotted as ordinates and number of cycles of load were plotted (to a logarithmic scale) as abscissas. For each type of joint the straight line which seemed best to fit the three

TABLE 4

TENTATIVE ENDURANCE LIMITS OF WELDED JOINTS FOR 2,000,000 CYCLES OF WHEEL LOAD

Wheel load at endurance limit is estimated as shown in Fig. 12

Type of Weld	*Weight of Rail lb. per yd.*	*At Endurance Limit*			*Approximate Ratio of Fatigue Strength of Weld to that of Rail*
		Wheel Load lb.	*Maximum Flexural Stress lb. per sq. in.*	*Maximum Shearing Stress lb. per sq. in.*	
Rail without weld	112	63,000	42,000	25,600	1.00
Rail without weld	131	79,000*	42,000*	24,200	1.00
Pressure butt weld (electric) Process D	131	more than 75,000	more than 33,100	more than 19,500	more than 0.79**
Pressure butt weld (gas) Process E	112	55,000	30,600	17,900	0.73**
Thermit weld	112	46,000	25,400	15,100	0.61**
Process C	131	52,000	23,000	16,000	0.66***
Fusion weld (gas) Process A	112	32,000	17,800	10,400	0.51†
Fusion weld (gas) Process B	131	22,000	9,700	6,700	0.28†

* Estimated on assumption that 131-lb. rail will develop as high flexural stress at endurance limit as 112-lb. rail. Maximum load which can be applied by machine 75,000 lb.

** Based on flexural stress at endurance limit. Failures by fatigue crack from surface.

*** Based on shearing stress at endurance limit. Fatigue failures were in web.

† Based on wheel load. Failures started from internal fissures.

or more test results was drawn, remembering that for a test in which 2,000,000 cycles of stress were withstood without fracture the plotted point cannot be *above* the load-cycle line. If none of the tests showed a "life" of 2,000,000 cycles the straight line for the three tests was extended until it intersected the ordinate for 2,000,000 cycles. This is shown in Fig. 12 for the tests of 131-lb. rail welded by Process B. Where one of the specimens ran to 2,000,000 cycles or over without fracture the straight line was drawn through the points for the two specimens which did fail. This is shown in Fig. 12 for the 112-lb. rail without weld and 112-lb. rail specimens welded by Process C. These endurance limits are distinctly more uncertain than the endurance limits of small polished specimens tested at high speeds, and determined from six or more specimens. However, the differences which they show are believed to be significant. Table 4 shows the tentative endurance limits determined in this manner. In determining the probable endurance limit for 131-lb. rail without weld it is evidently more than 39,600 lb. per sq. in. maximum flexural stress, since in the tests of the Process D welds the rail itself adjacent to the weld and directly over the supporting block was subjected to 1.2 times the stress in the center of the weld which was 33,100 lb. per sq. in. and failure occurred neither in the weld nor in the rail. It was then assumed that the 131-lb. rail did develop a maximum flexural stress as high as 112-lb. rail, that is, 42,000 lb. per sq. in. and the wheel load and maximum shearing stress accompanying this flexural stress were computed. The right hand column in Table 4 gives the approximate ratios of the fatigue strengths of the welds to that of the rail which were developed in these tests.

Again it is noted that welded rails should *not* be judged by the results of rolling-load tests alone. Lack of homogeneity shown by etch tests and microscopic examination, variation of strength, ductility and toughness qualities as shown by the tests of specimens cut from the joints—these factors must be given consideration. It must also be remembered that all the welded joints tested in the rolling-load machine were made with the knowledge that they were test joints, and this might make them either better or poorer than the average joint welded under service conditions. It is inevitable that joints made by the firm regularly doing rail welding and known to be used for tests of their product would be made with somewhat more care and closer inspection than is the case in

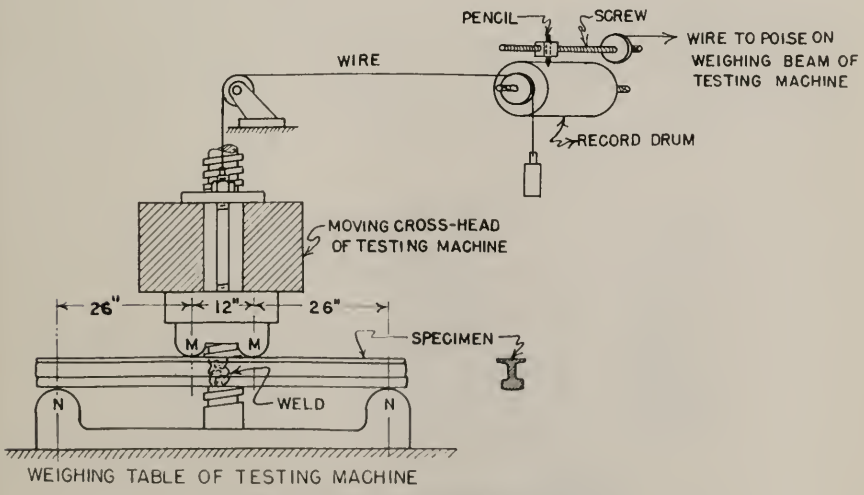


Fig. 13. Bend Test Rig with Specimen.

routine welding. This is in no sense a reflection on the honesty of the producers, it is merely the inevitable increase of carefulness which is present when a man knows he, or the product of his firm, is under examination. Now this very increase of carefulness may defeat its own object. Conditions accompanying the making of test joints are somewhat different from those accompanying the making of service welds, and the very additional care used, and the slowing down of the welding process which often happens may tend to make the test joints poorer than the average joint turned out.

In all consideration of welds the occasional occurrence of a poor weld must be recognized. There is at present no reliable non-destructive test for poor welds, and there are very few, if any, data on the probable frequency of occurrence of poor welds in rail joints. These considerations, together with considerations of the relative seriousness of failure of joint bars and of welded joints in rails must be factors in deciding whether or not to use welded rail joints in track.

V. BEND TESTS AND DROP TESTS OF WELDED JOINTS

By N. J. Alleman and H. F. Moore

14. A Comparison of Bend Tests and Drop Tests for Rails:—The standard drop test for rails consists of striking the rail, which is mounted over a span of three or four feet on a spring-supported anvil, with a falling weight, or "tup". The tup weighs 2,000 lb. and falls from a distance of from 18 to 22 ft., depending on the weight per yard of the rail. It strikes the test specimen at mid-span. This is a "pass or fail" test and gives very little information about the strength of the rail. Force is not measured at all and, if repeated blows are used until the rail breaks, only the energy required to fracture the rail and to compress the springs is indicated, and that only in "steps" of about 40,000 ft.-lb. Moreover, the distribution of energy between rail and springs is variable for different sections of rail, and for rail steels of different elastic strength.

In a cross-bending test of a rail, if a load-deflection diagram is plotted up to fracture the area under that diagram is a measure of the energy required to fracture the rail. A number of investigations* have shown that up to a certain critical speed,—a speed higher than that acquired by a weight falling 22 ft.—the energy absorbed is about the same for a given specimen of a given steel whether the load be applied slowly or rapidly. Moreover, in a bend test strength values are determined as well as energy values.

* For these references and a fuller discussion of the relative advantages of the bend test, see the Fifth Progress Report of the Rails Investigation

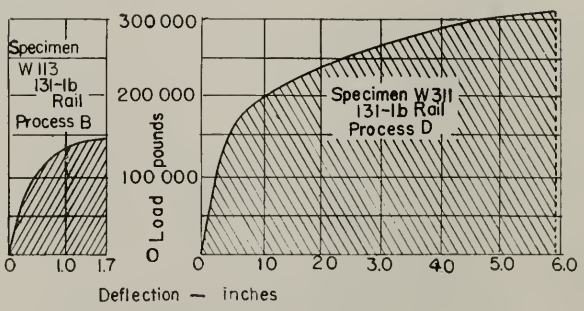


Fig. 14. Typical Bend-Test Load-Deflection Diagrams.

TABLE 5

RESULTS OF DROP TESTS OF WELDED RAIL SPECIMENS

Standard MCB testing machine and recommended AREA testing procedure used. Specimens tested head-up

Specimen No.	*Weight of Rail lb. per yd.*	*Welding Process*	*Height of Drop of 1-ton tup, ft.*	*Number of Blows for Fracture*	*Elongation in each inch of gage length on tension side, in.*
W 3	112	A	20	1	----------
W 23	131	A	22	1	0–1–3*–2–0–0
W 124	112	B	20	1	0–0–1*–0–0–0
W 102	131	B	22	1	0–1–3*–0–0–0
W 259	112	C	20	1	----------
W 210	131	C	22	1	----------
W 304	131	D	22	2	3–3–7*–3–4–3
W U4	112	E	20	1	3–4–2*–0–4–4

* Mea-urement acro-s fracture.

TABLE 6

RESULTS OF BEND TESTS OF WELDED RAIL SPECIMENS

Specimens tested head-down

Specimen No.	*Weight of Rail lb. per yd.*	*Welding Process*	*Maximum Load before Fracture lb.*	*Energy for Fracture ft. lb.*	*Deflection at Fracture in.*	*Elongation in each inch of gage length on tension side in.*	*Remarks*
Rail**	112	None	225,000	75,000	4.0	----------	
Rail**	131	None	300,000	100,000	5.0	----------	
W 4	112	A	124,200	4,200	0.71	0–0–0–2*–0–0	Lap side of head
W 22	131	A	168,500	7,360	0.53	0–0–0–1*–0–0	Lap side of head
W 113	112	B	140,500	6,900	0.92	0–0–0–0–0–0	Lap web & base
W 105	131	B	79,400	867	0.21	0–0–0–0–0–0	Lap at junction, head and web
W 253	112	C	193,900	23,370	1.33	1–1–1–1*–1–2	
W 203	131	C	231,500	22,200	1.65	1–1–1–2*–1–1	
W 311	131	D	315,100	121,500	5.98	7–6–10*–9–7–7	
W 404	112	E	217,600	42,600	3.16	----------	
W 405	112	E	239,200	72,100	4.70	3*–3–4–6–6–6	

* Measurement across fracture.
** Values for rails without welds taken from records of bend tests made by the Rails Investigation. Minimum values for crack-free rails recorded here.

15. Drop Test Results:—Both drop tests and bend tests have been made on specimens of welded rail. The drop tests were the standard drop tests for rails. The rails were tested "head up" (base in tension), and test results for rails welded by Processes A, B, C, D, and E are given in Table 5. It will be noted that only the joints welded by Process D passed the requirement of one blow without fracture.

16. Bend Test Apparatus and Test Results:—Fig. 13 shows in diagram the testing apparatus and the specimens used for the bend tests of welded joints. It is believed that this figure is self explanatory. Fig. 14 shows (reduced) two typical load-deflection diagrams. The ordinates of these diagrams measure strength values, the abscissas measure ductility values, and the area under the entire diagram measures energy absorption up to fracture which is here designated as "toughness."

Table 6 gives the results of the bend tests so far performed on welded rail joints. All specimens were tested "head down" (head in tension). The specimens for Process D welds gave results, both for bend tests and for drop tests, which would be regarded as satisfactory for rail without welds.

Appendix

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MEMOIR

John G. Sullivan

Died August 7, 1938

John G. Sullivan was born at Bushnell's Basin, N. Y., on January 11, 1863, the son of Thomas and Honora Sullivan. He received his education at Fairport high school and Cornell university, Ithaca, N. Y., from which he was graduated in June, 1888, with the degree of C.E.

Commencing as a rodman in the service of the Great Northern Railway, Mr. Sullivan worked up in the usual way to the position of assistant engineer of the Spokane Falls & Northern Railway in 1890, then becoming assistant engineer on the Pacific extension of the Great Northern Railway.

In July, 1893, Mr. Sullivan went to Canada as assistant engineer on the Alberta Railway & Coal Company, becoming locating engineer for the Butte, Anaconda & Pacific Railway in 1894, principal engineer for the Kaslo & Slocan Railway in 1895, and reconnaissance engineer of the Columbia & Western Railway in 1896. From that time Mr. Sullivan occupied various positions with the Canadian Pacific Railway, becoming principal assistant engineer of the Columbia & Western, and, on its completion, being appointed division engineer of construction for the Canadian Pacific at Winnipeg, Man. From the date of this last advancement until 1905, he had entire charge of surveys and construction of new lines built by the Canadian Pacific west of Fort William, Ont.

From 1905 to 1907, Mr. Sullivan was assistant chief engineer of the Panama canal and for three months, during the absence of the chief engineer, Mr. John F. Wallace, in Washington, D. C., he was acting chief engineer in charge of all works.

Returning to Canada in 1907, Mr. Sullivan became manager of construction, Eastern Lines, for the Canadian Pacific Railway at Toronto, Ont., going to Montreal, Que., in 1908 as assistant chief engineer of Eastern Lines. In 1911 he returned to Winnipeg as assistant chief engineer of Western Lines, and in the same year became chief engineer of Western Lines. In 1915 Mr. Sullivan became chief engineer of the Canadian Pacific System, which position he held until 1918, when he became consulting engineer for the company.

After 1918 Mr. Sullivan carried on a private practice in engineering, during the course of which he served, from 1919 to 1922, as chairman of the Manitoba Drainange Commission. In 1919 he prepared a report on the economics of the proposed government hydro-electric power distribution system in Manitoba, and during the next two years acted as consulting engineer in connection with the arbitration between the Canadian government and the Grand Trunk Railway. In 1925 Mr. Sullivan was called to England as an expert witness before a committee of the House of Lords, on a proposed tunnel from Liverpool to Birkenhead, under the Mersey river. This tunnel has since been constructed. He also acted as consultant in reporting to the Government of British Columbia on the Pacific Great Eastern Railway; to the Government of Manitoba on the policy it should adopt in regard to the hydro-electric system; to the Southern Railway Company on its line between Cincinnati, Ohio, and Chattanooga, Tenn., and to the Denver & Salt Lake Railway on the practicability of ventilating the Moffat tunnel. In 1925 Mr. Sullivan was appointed member of a Board of Engineers to make a joint report to the Canadian Pacific and Canadian National railways on the railway situation in the Peace River country.

One of Mr. Sullivan's particularly outstanding pieces of work was the Canadian Pacific's double-track Connaugh tunnel under Mount Macdonald in the Selkirk moun-

John G. Sullivan

tains, this work being entirely under his supervision, and being, when built, the longest tunnel in the western hemisphere. The method employed in its construction was at that time unique, and his system of using radial drilling in the center heading, permitting the handling of 85 percent of the material in the tunnel with machinery, and resulting in the cheapest construction and fastest time made up to that date in western tunnels.

Mr. Sullivan became a naturalized Canadian citizen in 1905. He served as an alderman for the City of Winnipeg from January, 1920 to January, 1928.

He was a member of the American Railway Engineering Association from 1902; served as a member of Committees 1—Roadway, 2—Ballast, and 16—Economics of Railway

Location, being chairman of the latter for three years. After serving as a director and second and first vice-president, he was president of the Association for the year ending March, 1918, and was accorded honorary membership in the Association at the annual meeting in 1938. In 1919 the Association published in Volume 20 of its Proceedings a most interesting monograph by Mr. Sullivan, entitled "A Study of the Mechanics of Curve Resistance".

Mr. Sullivan became a member of the American Society of Civil Engineers in 1899, and a member of the Engineering Institute of Canada in 1900, occupying the presidency of the Engineering Institute of Canada in 1922. He was awarded the Sir John Kennedy Medal of the Institute in 1936, this being the highest honor the institute can bestow. In May, 1936, the University of Manitoba conferred upon him the honorary degree of Doctor of Laws.

He was a member of the Manitoba Club and of the St. Charles Country Club, Winnipeg.

In 1894 Mr. Sullivan married Miss Sarah Farrell, of Lodi, N. Y., who predeceased him in 1933. Surviving him are two sons, Paul L., of British Columbia, and John T., of Temagami, Ont., and two daughters, Mrs. K. L. Peustow, of Madison, Wis., and Mrs. John R. Lindsay, of Winnipeg.

Mr. Sullivan's death in Winnipeg, on August 7, 1938, closed a most active and distinguished professional career. He had a wide circle of friends throughout the United States and Canada, who feel keenly the loss of his true and whole-hearted friendship.

J. M. R. Fairbairn, *Chairman,*
J. C. Irwin,
G. W. Kittredge,
Committee on Memoir.

DISCUSSIONS

DISCUSSION ON CLEARANCES

(For Report, see pp. 75–76)

(President Morrow presiding.)

Chairman A. R. Wilson (Pennsylvania): Your committee is making a report on the second assignment, namely, Clearances as affected by half-through inter-track girders and structures, third rail, signal and train control equipment, collaborating with Electrical section, Engineering division, and with the Mechanical and Operating divisions. This report is submitted as information. However, a few comments should be made.

The diagrams accompanying the report are found on the next page. Fig. 1a indicates the position of the girder on a grade separation project. I believe it is apparent that the height or distance to top of girder is not only a function of the flange width but also a function of the girder centers. It is shown in relation to the railroad bridge clearance diagram which now appears in our Manual.

The second figure, Fig. 1b, indicates the railroad bridge clearance diagram with a girder, indicating encroachment by high platforms, third rail and inter-track fences. The amount of encroachment of a girder of this depth is also a function of the track centers.

I believe it must be recognized that the railroad bridge clearance diagram must be modified to permit certain encroachments in the lower corners, as it is impossible in the design of a structure of any span within reasonable girder lengths where multiple tracks are involved, to space the girders so as to keep them out of the bridge clearance diagram without materially affecting the track centers.

Since this report was published, we have received constructive criticism particularly from Mr. Fanning, chief engineer of the Erie. The committee in the coming year will endeavor to develop a diagram for adoption, which will permit encroachment on the standard diagram, particularly in the lower corners.

In view of this attempt of the committee, we turn to page 75. It is the desire of the committee at this time to withdraw from the paragraph on Subject 2, that part reading "and that a note be placed in the Manual under the chapter on Clearances, calling attention to this information as appearing on page 75 of Volume 40," for the reason that if such a diagram is adopted, we do not believe it necessary to refer in the Manual to this information.

The committee would also like to read into the Proceedings a review of its activities in connection with the Association of American Railroads.

"On October 25, 1938, Mr. Symes designated the following to act as a committee to review the Railway Line Clearance publication with respect to clearance diagrams contained therein and any other matter presented by the AAR for inclusion in the publication:

Mr. V. R. Hawthorne, secretary, Mechanical division, AAR, Chicago, Ill.
Mr. W. C. Kendall, chairman, Car Service division, AAR, Washington, D. C.
Mr. G. C. Randall, chairman, Gen. Com., O-T division, AAR, Chicago, Ill.
Mr. A. R. Wilson, chairman, Special Committee on Clearances, AAR, Pennsylvania Railroad, Philadelphia, Pa.

This committee held its first meeting on October 31, 1938, at which time various sections of the publication were assigned to the respective members for review.

"It was the unanimous opinion of those present that an equipment clearance diagram should be developed by the Engineering division, in collaboration with the

Mechanical and Operating-Transportation divisions, to be used in connection with the application of Car Service Rule 14 (d). The present 'approved clearances' of the Association are limited to the *third rail clearances*. The suggested diagram will broaden this rule, so that responsibility for cost of transfer will be placed upon the delivering road when the dimensions of the car exceed those shown in the proposed equipment clearance diagram.

"Subsequently Mr. Symes approved this recommendation, and the Engineering division representative was requested, in collaboration with the Mechanical division, to develop such an outline of equipment to be used in connection with Car Service Rule 14.

"The work originally assigned to the committee, namely, reviewing the Railway Lines Clearance publication, has been completed, and that in connection with the car equipment diagram is well advanced."

That concludes our report. The committee will welcome any suggestions in connection with the preparation of the diagram permitting encroachments on the standard bridge clearance diagram.

President Morrow: If there is no discussion on these matters, the committee will be excused with the thanks of the Association. (Applause.)

DISCUSSION ON STANDARDIZATION

(For Report, see pp. 65–69)

(President Morrow presiding).

Chairman E. M. Hastings (Richmond, Fredericksburg & Potomac): In these first-day-morning programs, for several years past, it has fallen to the Committee on Standardization to start the wheels of work turning. It is rather hard to settle down to cold affairs of the Association, after listening to the inspiring talks that have given us a great deal of food for thought for the days ahead.

Your Committee on Standardization, as you know, is composed of the chairmen of all of the standing committees of the Association. Its work is not to bring to you year by year something for adoption for the Manual, nor recommendations for your vote or your approval. It is for informative purposes only. The three familiar subjects that are assigned to your committee and reported on each year can only be reported on as progress.

Your committee has kept in touch with the activities of the associations concerned with standardization. You will find on pages 66 to 69, the report of the activities of the American Standards Association and of the Canadian Engineering Standards Association.

Since the publication of Appendix A in the Proceedings, Volume 38, page 466, we have not reported any amendments or additions, although there are a few that shou'd be made, but for economic reasons it was felt unnecessary to republish the large amount of information that is contained in that appendix.

But, as this is the final or closing year of my chairmanship of this committee, will you permit me to say to you again: There is stored up in the Manual of Recommended Practices of this Association a vast amount of information, of practices and of specifications and, if you please, of standards that will all work to the economic operation and maintenance of our railroads. That volume, and what it contains, is worthy of more attention than it receives. You have heard that matter very ably referred to this morning in the splendid address that was given by Mr. King, the new vice-president of the Association of American Railroads. It certainly seems to me, as I think it must be apparent to every one of you, that what we need to do as members of the American Railway Engineering Association is to use the Manual and what it contains for the purposes for which it was designed.

Hence, I recommend to you again a study of the appendix that was presented a few years ago and call your attention to the amendments and the additions and deletions from the Manual that have taken place since then, and the use of this Manual for the purpose that it was intended on each of your individual properties.

In leaving the work of the Standardization committee may I be permitted to say that it has been a real joy. It has brought me into closer contact with many phases of the Association work, and I give it up with regret. It will be in splendid hands, however, for the years ahead, as we are naming Mr. Frank Nicholson, director of the Association, as the new chairman of the committee.

The report is presented only as information. (Applause).

President Morrow: Mr. Hastings, you are only being allowed to give up this committee because you are going to be given larger responsibilities.

The committee is now excused with the thanks of the Association. (Applause).

DISCUSSION ON SIGNALS AND INTERLOCKING

(For Report, see pp. 183–186)

(President Morrow presiding.)

Chairman H. G. Morgan (Illinois Central): The report of Committee 10 is on page 183. It has been prepared by Mr. Post, the subcommittee chairman, and I will ask him to present it to you.

Mr. W. M. Post (Pennsylvania): As stated under our Assignment 1, Developments in railway signaling, there has been none to report since we reported to the annual meeting in 1938. However, two developments in highway crossing protection were reported on yesterday at the Signal section, and I believe it would be proper under this assignment to read two short reports on these into the record.

No. 1 is Automatic Crossing Gates.

"Automatic crossing gates extending over the righthand half of the highway approaching the tracks have been installed at railroad highway grade crossings to provide additional protection to meet special conditions. The section of the roadway normally used by a vehicle driver when approaching a crossing is obstructed by the gate arm during the approach and passage of train or trains, the gate arms staying in the lowered position if a second train is approaching. The gates do not obstruct the path of the vehicle when on the crossing as only half of the roadway is obstructed. The single gate arm is mounted on the side of the highway and operates on the closed-circuit principle. Each gate arm is equipped with two-way indication red lights, the lights being extinguished while the arm is in the raised position. As of July 1, 1938, approximately 85 short-arm gates were installed at 41 crossings on 19 railroads."

As of December 31, 1938, approximately 168 short-arm gates were installed at 59 crossings on 30 railroads.

I would also like to report on a development called "No right-turn or no left-turn signs." No right-turn or no left-turn illuminating signs have been developed to meet certain railroad and highway requirements where definite information should be displayed on the approach of trains, because a highway is adjacent and parallel to a railroad at a highway crossing. With a train approaching the crossing, a turn across the railroad track should not be made from the parallel highway, although through movements on the highway parallel to the railroad can be made with safety. A flashing yellow unit is mounted above the no right-turn or no left-turn sign.

When a train approaches a crossing, the yellow light flashes to attract attention, and the no right-turn or the no left-turn sign is illuminated, indicating to traffic on

the parallel highway that turns should not be made across the railway tracks. In addition to these signs, the highway crossing signal would be located on the highway crossing the railroad. As of July 1, 1938, there were approximately 41 signs of this type installed, and as of December 31, 1938, approximately 50 signs of this type were installed.

These reports are presented as information.

Under Assignment 2. The principal current activities of the Signal section, AAR, by synopsis, supplemented with list and references by number of adopted specifications, designs and principles of signaling practice, we present a list of what has been done by the Signal section. Of course, for the details of these activities, it would be necessary to go to Signal section literature. However, I would like to make comments on a few of these activities.

No. 1, on page 183, Costs involved in stopping trains, attention was called last year to formulas which had been set up by which the cost of stopping a train may be calculated if the necessary data pertaining to each case are available. The Committee on Economics of Railway Signaling has prepared charts and curves for certain gross weights of trains and types of locomotives on level tangent track by means of which the approximate horsepower-hours of work wasted in making a stop may be determined by a direct reading from the chart. The committee has also prepared simple formulas for calculating the cost of fuel and water wasted in making a stop. This committee will extend these charts and formulas to cover grades and curves, and possibly additional types of locomotives.

If this committee can prepare charts and curves which can be used as a short-cut method for determining the cost of stopping a train under all the variables, such as curves, grades and different weights and types of locomotives and cars, a valuable contribution will have been made to the economics of railroad operation.

No. 2, Centralized traffic control on the Missouri Pacific Railroad: This is a report of an economic study of a centralized traffic control installation on that road which resulted in an increase in the average speed of freight trains from 19 miles an hour to 23 miles per hour, and of passenger trains from 39 miles per hour to 46 miles per hour.

No. 8 is Necessary modification of direct-current track circuits in detail or in principle to insure reliable protection of rail motor cars of passenger or freight-carrying type. The Committee on Automatic Block Signaling presented an interesting report on several experiments which are being made to improve shunting of track circuits by lightweight equipment.

No. 13, Instructions for fire protection for interlocking stations and other buildings housing signal equipment. This report calls attention to many precautions which should be taken to reduce fire hazards to a minimum.

No. 25, Automatic train control and cab signals. This is a report bringing the statistics of automatic train control and cab signals up to date. As of July 1, 1937, there were 10,483 road miles, 20,234 track miles and 9,180 locomotives equipped for train control or cab signals, or both, in the United States.

(Mr. Post then made brief references to the remaining items in the report.)

Mr. Post: I would like to call attention again to the pamphlets on American Railway Signaling Principles and Practices prepared for the education of signalmen and others desiring to know more about signaling. They will prove especially valuable for young men entering railroad service. If these young men will secure these pamphlets from Mr. R. H. C. Balliet, secretary of the Signal section, 30 Vesey street, New York City, they will have access to the best information that can be procured on this subject, and if

they will study these bulletins, they will have a fair knowledge of signaling when they enter supervisory or administrative positions in the railroad field.

Chairman Morgan: Mr. President, that concludes the report.

President Morrow: Mr. Chairman, I want to congratulate you on the excellent presentation that has been made. The report will be received as information, and you are excused with the thanks of the Association.

DISCUSSION ON WOOD PRESERVATION

(For Report, see pp. 457–517)

(President Morrow presiding.)

Chairman C. F. Ford (Chicago, Rock Island & Pacific): Our first assignment, Revision of Manual, will be presented by Dr. A. L. Kammerer.

Dr. A. L. Kammerer (New York Central): Progress is reported in the study of specifications for treating processes and specifications for the treatment of various species and classes of wood.

A revision is presented in the section on water determination in the specification for creosote analysis now in the Manual. This revision consists of making certain minor changes of an editorial nature in the method now standard and calling this Method No. 1, see paragraphs 101 to 106.

A further revision consists of adding an alternative method designated as Method No. 2. This method is more rapid and convenient and can be used in cases where a water determination in creosote alone is desired. This is printed in paragraphs 109 to 121 To summarize: The committee recommends the acceptance of the editorial changes which have been made in the present standard for water determination designated as Method No. 1, and the adoption of an alternative method for water determination designated as Method No. 2.

I move that Method No. 2 be adopted as standard, and that the suggested editorial revisions of Method No. 1 be accepted.

President Morrow: You have heard the motion. Is there any discussion? (The motion, duly seconded, was put to a vote, and carried.)

Chairman Ford: The report of Subcommittee 2, Service test records for treated ties, will be found on page 463. This is the usual progress report made by this subcommittee and covers treated ties in service on various railroads. The report is submitted as information.

President Morrow: It will be received as information.

Chairman Ford: Subcommittee 3, Piling used for marine construction: The report covers long-time test pieces in the Canal Zone and other localities under observation.

This report is also submitted as information.

President Morrow: It will be received as information. Is there any discussion? You may proceed.

Chairman Ford: Subcommittee 4, Effect of preservative treatment by the use of creosote-petroleum, and zinc chloride and petroleum. This subject has been under consideration since 1924, and progress reports have been submitted from time to time covering the condition of the material under test.

This report covers a record of about a million ties treated with various preservatives, and, in most cases, only a small percentage of the total number of ties has been replaced, leaving the matter as a progress report for future consideration. The committee has done a great deal of work on the report, and I think the information presented will

make it possible for the members to make their own analyses of the various classes of treatment which will give them the most desirable results.

President Morrow: Is there any discussion on that report? If not, it will be received as information.

Chairman Ford: The report of subcommittee 5, Appendix E, Destruction by termites and possible ways of prevention, will be presented by Mr. W. A. Summerhays, in the absence of Dr. von Schrenk, chairman of this subcommittee.

Mr. W. A. Summerhays (Illinois Central): The 1933 proceedings give an outline of the work undertaken by this subcommittee. In the Proceedings of 1938 there is an outline of further development in which soil treatment is undertaken. It is found that some buildings are so constructed that the usual means of heading off termites cannot be carried out. This subcommittee is attempting to show that the soil can be poisoned sufficiently to prevent termites from coming into a building of that kind. The first test, which is reported in the 1938 proceedings, was not conclusive. It seems as though the plan is not working out. Dr. von Schrenk has gone into the matter in considerable detail and has now under way a further test which will be much more complete. Reading from this report, this test brings out these points:

A number of pressure-treated pieces will be placed. The successful results of the first series with trichlorbenzene led the committee to include in this second series not only a repetition of the 100 percent trichlorbenzene application, but also a considerable number of dilutions with petroleum. This seems desirable, due to the high initial cost of 100 percent of the compound. Included in this series are a number of posts which will be treated with two concentrations, using larger quantities of dilutions with petroleum to determine whether an application at some distance from the posts will have any effect.

A number of new compounds are included, which are listed in this committee's report. Dr. von Schrenk has just added two more compounds, and I wish he were here to tell you the names because I consider them unpronounceable, but hope they will be effective in this test.

The investigations into the activities of termites are very interesting. I think the Doctor stated in his report last year that termite activities have been found in every state of the Union. He mentioned yesterday, in discussion, that for the first time in his investigations he had found termites attacking a creosoted crosstie. He explained that this was in a side-track which was very seldom used, but it was interesting to learn that termites had gone into a creosoted tie and, he said, in great numbers. The report is offered as information.

President Morrow: Is there any discussion or comment on this report? If not, it will be received as information.

Chairman Ford: The report of subcommittee 6, Effect on preservative in treated ties in track due to blowing off locomotives on line of road, will be presented by the chairman of the subcommittee, Mr. C. S. Burt.

Mr. C. S. Burt (Illinois Central): Those of you who followed previous reports of the subcommittee will probably recall that our findings to date indicate a rather slight loss of preservative from treated ties in track due to continuous operation of the blow-off, but that loss is very small. It is the opinion of the committee that it has very little, if any effect on the ultimate service life of crossties. Our work during the past year, while on a somewhat larger scale, tends only to further support those views. On the other hand, the current trend of changes in the method of blow-off seems to point toward a lessening of whatever effect there may be on the life of crossties or the loss of preservative from

treated ties due to this operation. The report is offered as information, together with the recommendation that the subject be discontinued.

President Morrow: Is there any discuss.on or comment on this report? If not, it will be received as information.

Chairman Ford: The committee has nothing to report on Subjects 7 and 8. Subject 9 is, Present practice as to preservatives used. After this report was printed, it was found that there had been some omissions and some errors in the information as shown, and the committee would like the privilege of withdrawing the report.

President Morrow: That will be permitted. I take it that you do not want it published in the proceedings.

Chairman Ford: That is the thought I had in mind. I don't think it is very serious, but at the same time, the information was secured from the various railways, and we don't think we ought to publish something that isn't correct so far as their practice is concerened.

President Morrow: This report will be withheld, and the committee given an opportunity to re-present it next year.

Chairman Ford: That completes our report, Mr. Chairman.

President Morrow: Mr. Chairman, I think the committee should be congratulated upon its excellent report. Much to my regret, the committees were a little discommoded on account of our getting off schedule yesterday. I want to express my regret that that took place. The committee is excused with the thanks of the Association. (Applause.)

DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS

(For Report, see pp. 77–81)

(Vice-President Hastings presiding).

Chairman W. G. Nusz (Illinois Central): The first assignment is Revision of Manual. The uniform general contract forms were fully revised prior to the publication of the present Manual and no revisions are recommended at this time.

The second assignment is Form of agreement with public authorities for highway grade crossing elimination or separation, collaborating with Committee 9—Highways. This subject was assigned to Committee 20 prior to the federal government activities in grade crossing elimination. The committee obtained many agreements from different sections of the country and gave them careful consideration, submitting a tentative form in Bulletin 371 (Proceedings for 1935, Vol. 36, page 124). The committee believes no final form can be submitted at this time.

The third assignment is Form of agreement to cover operation of commissary and boarding outfits. The committee submits a tentative form of agreement as information (Appendix A). The fourth is Form of agreement for commercial signs on railway property. The committee has collected data on this assignment and a form of contract is in preparation and will be submitted next year.

The fifth is Form of lease for air-right development. The committee has collected information and agreements covering this assignment and considerable progress has been made. It is expected that a form will be submitted to the Association next year.

The report of the committee is entirely a progress report this year. It is the usual practice to submit agreements to the Association at its convention for criticism and suggestions before they are adopted by the Association. We are always anxious to receive suggestions from any members interested, and they will be given careful consideration by the committee.

Vice-President Hastings: This committee has presented as progress this year a Form of Agreement to Cover Operation of Commissary and Boarding Outfits. Is there anyone present who desires to ask the committee any question concerning this form?

Mr. W. A. Radspinner (Chesapeake & Ohio): On this question of fire insurance—commissary or boarding outfits are leasing railroad property, and they should agree to let the fire-prevention inspectors of the railroad inspect their property and see that they carry out the practices of the railroad.

Chairman Nusz: The committee will consider that before it presents the final report.

Vice-President Hastings: Are there any others? If not, the committee is excused with the thanks of the Association. (Applause).

DISCUSSION ON HIGHWAYS

(For Report, see pp. 291–303)

(President Morrow presiding.)

Vice-Chairman Bernard Blum (Northern Pacific): The first subject, Revision of Manual, relates to highway crossing signs and signals. Mr. Gault, chairman of the subcommittee, will present the studies that have been made, which are recommended for adoption.

Mr. P. M. Gault (Missouri Pacific): In Appendix A, beginning on page 292, the committee presents some additional drawings of another highway crossing sign. Pages 293, 294 and 295 show the assembly and detail drawings of the new 6-ft. 50-deg. reflector type crossing sign, which is intended for use at crossings where something more than the ordinary sign is required, but which are crossings not considered sufficiently important to warrant automatic signals. These three drawings have already been approved by the Signal section, and the committee recommends the adoption of all three for publication in the Manual in place of Figs. 902 and 903 now appearing in the Manual and I so move.

(The motion was duly seconded, put to a vote and carried.)

Vice-Chairman Blum: The second subject assigned to the committee is Economic aspects of grade crossing protection in lieu of grade separation. The subcommittee has continued its work on this subject but is not ready to report at this time. Similarly, on the third subject, Design and specifications for highway crossings at grade over railway tracks, further work has been done but no new type of crossing has been definitely completed. During previous years, specifications have been presented and adopted. On the fourth subject, Comparative merits of various types of grade crossing protection, the committee has made progress but is not ready to submit a report. The next subject is Develop drawings showing general requirements for installations of automatic gates. Work on this has been carried on by the subcommittee, and Mr. Maro Johnson, the subcommittee chairman, will present the report.

Mr. Maro Johnson (Illinois Central): This report is Appendix B on page 292, but the drawings referred to are on pages 296, 297 and 298. These drawings supplement the requisites for automatic crossing gates which appear in Appendix F, and are presented for adoption and publication in the Manual, and I move that they be so handled.

(The motion was duly seconded, put to a vote and carried.)

Vice-Chairman Blum: The next subject, No. 6, Method of classifying grade crossings with respect to hazard. Considerable work has been done during the past year by the subcommittee of which Mr. Lewis is chairman, and he will present the progress report which is shown on page 299 under Appendix C.

Mr. E. R. Lewis (Michigan Central): This report takes cognizance only of the chief factors which enter into the classification of grade crossings with hazards. There

are many others that are not sufficiently widespread to include in this report. The object is to get only the chief factors in order to make them apply to countrywide application. There are two tables, Table A, Physical Characteristics, of which there are six general subdivisions, two of them on page 300, and Table B, in which I call attention to No. 2, Railway Traffic, which should read Highway Traffic.

Drawings are of special importance in this treatment of crossings as to hazards. They should be in such detail as to indicate the basis on which these chief factors can be evaluated. Weighting is not, of course, within this subcommittee's assignment for this year; that will have to come at a later date. This report is offered as information.

President Morrow: It will be so received.

Vice-Chairman Blum: Subject No. 7, Prepare requisites for floodlighting of railroad-highway grade crossings, was assigned to this committee through the demand from several of the states which, under certain conditions, deemed it necessary to floodlight rather than provide automatic crossing protection such as flashing lights, such crossings being those at the end of terminal yards where considerable switching is done, where cars are stopped on the crossing for some minutes, and in which cases a number of accidents have occurred.

The subcommittee has prepared, I think, a well written set of instructions under the leadership of Mr. Taylor who will now present the report which is ready for action on the part of the convention.

Mr. C. A. Taylor (Chesapeake & Ohio): This report is Appendix D on page 301, Requisites for floodlighting of railroad-highway grade crossings. The committee is presenting this for inclusion in the Manual. I will read the paragraph numbers and pause for any discussion * * *.

I move that this matter be adopted for inclusion in the Manual.

(The motion was duly seconded, put to a vote and carried.)

Vice-Chairman Blum: The next subject, No. 8, is on page 302, Lamps on manual and automatic crossing gates. This report is given as information at this time until the matter of design and other items in connection with the lamps has been perfected. Attention is called to the next report, on Requisites for automatic crossing gates, in which a revision will be offered for your consideration that will have its effect on Subject No. 8. I don't think it is necessary to call attention at this time to the change in Subject 8 as such change will follow next year when the subject itself will be offered to you for adoption.

I think Mr. Young is not present. The subject matter of No. 8 is shown under Appendix E on page 302. It provides for the methods applying to the location and operation of the lamps on crossing gates, both manual and automatic. The information as now given is simply for your information and for further consideration next year. Undoubtedly the Board of Direction will reassign this subject to Committee 9.

The next subject is No. 9, Requisites for automatic crossing gates, presented on pages 302 and 303.

This is the second time that these requisites have been presented to you for approval and adoption. Last year you approved them as presented, but when they went to the Joint Committee on Grade Crossing Protection of the AAR they were referred to the Signal section, which raised objections to the lights on the gate arms, and demanded a change. The subject was referred back to your Committee 9, and this year, in order to have uniformity, we acceded to the Signal Section's views.

Yesterday, when the Signal section had these revised rules before it for adoption, it reversed its position and adopted what we had presented two years ago. Inasmuch

as the section has now agreed to what we presented originally, I think we should be willing to accept its revision.

The change relates to requisite No. 9 on page 303, which reads:

"Each gate arm, extending over the roadway, shall have two red lights for each lane of traffic it protects, shining in both directions along the highway for night indication."

Your committee recommends that this paragraph be revised as follows:

"Each gate arm, extending over the roadway, shall have three red lights shining in both directions along the highway. The light nearest the tip of each arm shall burn steadily and the other two lights on each arm shall flash alternately."

The change, briefly, is this: For instance, in a four-lane highway, as published, there would be eight lights in each directions. As revised, there would be three lights. No matter how many lanes of traffic, there are three lights, two of which are flashing and the one on the left end of the arm burns steadily, so as to draw attention to the end of the arm.

I move the adoption of the revised No. 9 as I read it, which also means that paragraph 16 will be eliminated and paragraph 17 becomes 16.

(Mr. Blum then repeated the substance of the rules, following which his motion was seconded.)

President Morrow: You have heard the motion and the discussion given by the chairman. Is there any other discussion at this time that anyone has in regard to this subject?

Mr. J. C. Irwin (Boston & Albany): Do I understand that these requisites now agree with what the Signal section passed on?

Vice-Chairman Blum: Yes. Mr. Gault, a member of Committee 9, is the chairman of the Signal section committee that handled this yesterday at the Signal section convention.

Mr. Irwin: Is it identical with what we approved previously?

Vice-Chairman Blum: It is substantially.

Mr. Irwin: Then it is not necessary to approve them but simply stand on what we approved.

Vice-Chairman Blum: I believe it will be advisable because there have been some minor revisions, not of any great moment. I think it would be well to have it accepted now.

Mr. W. M. Post (Pennsylvania): Mr. Blum is partly correct in his statement. Two or three years ago, I believe, the requisites were prepared by Committee 9, and they did provide for flashing light signals. Mr. Rudd at that time suggested that they be changed to steady burning light signals, and it was changed, I am quite sure, before they were presented to the meeting. Last year, however, the requisites did contain a provision that the lights should be steady burning, and that was what was approved at the last meeting. There were some other changes. "I. Automatic gates where installed shall be provided as an adjunct to AAR recommended automatic crossing signals." I think last year No. 1 was quite different. There are three or four other changes that make them, in my opinion, substantially different from the requisites that were approved at the last annual meeting.

Vice-Chairman Blum: Mr. Chairman, Mr. Post, I stand corrected. We did originally make them as I said, and in an informal meeting I think, with Mr. Rudd, who handled it for the Signal section, we changed it just prior to having it published as shown in the last Proceedings. Mr. Post is correct in his history of the case.

Mr. Gault: I would like to add a word to what Mr. Blum has said. In conference between this committee and Committee 8 of the Signal section, the wording was arranged to be identical for both presentations. While it may not have been understood at the meeting, the wording used by both organizations should be the same. One of the reasons for the change back to flashing lights yesterday in the Signal section meeting is that 13 states have specified and purchased gates of this type since the last meeting, and in each one of these states the requirement is as stated in the new paragraph 9.

(Mr. Blum's motion was then put to a vote and carried.)

Vice-Chairman Blum: That completes the report of Committee 9.

President Morrow: It was the expectation at this time that Mr. MacDonald of the Bureau of Public Roads would be with us to give us a word in connection with this. Mr. MacDonald, much to our regret, advised that he was unable to be here on account of illness.

Mr. Chairman, the committee is to be congratulated on its excellent report, and it is excused with the thanks of the convention. (Applause).

DISCUSSION ON ROADWAY AND BALLAST

(For Report, see pp. 519–542)

(Vice-President Fanning presiding.)

Chairman A. E. Botts (Chesapeake & Ohio): The committee reports progress on Assignment 1, Physical properties of earth materials, particularly their effect upon roadbed performance; structural bearing power, and on Assignment 2, Natural waterways, particularly drainage areas, water runoff, and size of openings.

Assignment 3, Culverts, particularly factors determining their location and type, which is recommended for publication in the Manual, will be presented by Mr. Swartout, chairman of the subcommittee.

Mr. W. C. Swartout (Missouri Pacific): I will present first the report on factors determining the location and type of culverts. A report on this subject was presented to the convention in 1938 as a progress report for information. Further study indicated the desirability of some revisions in the report, which have been made. I appreciate that a hard and fast line can hardly be drawn between what is and what is not proper material for the Manual, but it is the judgment of the general committee that the matter now offered can be classified as recommended practice, for it outlines the basic principles to be observed in determining the location and type of culvert.

(Mr. Swartout then read the subheadings A to H, inclusive, and his motion that the subject matter be adopted was duly seconded, put to a vote and carried.)

Mr. Swartout: The second part of our report is on Vitrified pipe culverts, specifications. The committee has made progress in the preparation of specifications for vitrified pipe intended for use as culverts under railroad and highway loadings, working with a similar group representing Committee C-4 of the ASTM, and confidently expects to have a tentative specification ready for presentation to the 1940 convention. Therefore, we can only report progress for this year on that subject. Any member of the Association who has any suggestions to offer on necessary or desirable matter to be included in a vitrified pipe specification, is requested to send them to the chairman of the committee, Mr. Botts, or to me. This is offered as information only.

Vice-President Fanning: It will be so received.

Chairman Botts: Assignment 4, Formation of the roadway, particularly width of roadbed and angle of slopes, is recommended for publication in the Manual. It will be presented by Mr. Paul Chipman, chairman of the subcommittee.

Mr. Paul Chipman (Pere Marquette): The report of this subcommittee will be found under Appendix B, on page 524. Recommendations as to widths and slopes.

(Mr. Chipman read the first two paragraphs of the report, following which he read merely the various subject headings to the bottom of page 528. He then read the conclusions on page 529 in full.)

Mr. Chipman: I move that this material be placed in the Manual, and that the present material under the heading "A. Width of Roadway at Subgrade", and under the heading "B. Slopes" be deleted.

(The motion was seconded, put to a vote and carried.)

Chairman Botts: The committee reports progress on the fifth assignment, Roadway drainage, and on the sixth assignment, Roadway protection, particularly slope protection. Assignment 7 is Tunnels, particularly ventilation. This will be presented by Mr. Alexander, chairman of the subcommittee.

Mr. F. W. Alexander (Canadian Pacific): The report of this committee will be found on pages 529 to 531, inclusive. The first portion gives a short review of the method pursued in gathering information. Following this, a brief analysis of a few outstanding items of information is tabulated on the inserts between pages 530 and 531. In turn, following these tables, is a bibliography of articles on tunnel ventilation. The report is presented as information with the exception that Conclusions 1 to 4 on page 531 are recommended for approval and printing in the Manual. As this report has been in your hands for some period, unless there is some objection, I will read only the conclusions for their approval and printing in the Manual.

(Mr. Alexander read the four conclusions on page 531.)

Mr. Alexander: The committee recommends that conclusions 1 to 4, inclusive, be approved and printed in the Manual preceding the matter under Ventilation. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Botts: Progress is reported on Assignment 8, Fences, particularly fence posts and braces; corrosion-resisting fence wire, collaborating with appropriate subcommittees of committee A-5 on Corrosion of Iron and Steel, ASTM. Assignment 9 is Signs, particularly roadway signs required and close clearance sign. The report will be delivered by Mr. Drumeller, chairman of the subcommittee.

Mr. L. J. Drumeller (Chesapeake & Ohio): This report is under Appendix D on pages 535 to 540. At the convention of 1937 this committee presented for discussion the subject of "Signs, particularly roadway signs required." The report was concluded with an earnest request for constructive criticism and suggestions from interested members. No criticism has been offered, and the committee presents the following report for adoption and publication in the Manual, and recommends that the subject be discontinued, excepting study under heading 904-Design of Signs.

Under "Definitions of Terms" insert the following definition in the Glossary:

"Roadway Sign.—Any marker displayed on or near the right-of-way for instruction or information of employees or others."

Under heading 901. Roadway Signs Required, beginning at top of page 536 we have included only such signs as are believed essential for the proper operation and maintenance of line of railway.

(Mr. Drumeller then read all of the titles and sub-titles on pages 536, 537 and 538, concluding with "Paint".)

Mr. Drumeller: I move that this matter be adopted for inclusion in the Manual as recommended practice.

(The motion was seconded.)

Vice-President Fanning: You have heard the motion. Is there any discussion?

Mr. J. L. Pickles (Duluth, Winnipeg & Pacific): I think under A, "No Trespass" signs would not come under this heading, "actually necessary for the proper operation and maintenance of a line of railway." When you say they are to be erected at places where trespassing is especially dangerous or undesirable, the inference is that there are other places where trespassing is permitted. I don't see the necessity of a sign in this category.

Mr. Drumeller: In preparing this report, we canvassed a good number of railroads and found that possibly 75 percent of those we canvassed have a "no trespass" sign, so, apparently they are necessary.

Vice-President Fanning: Is there any further discussion? Does anyone have anything to say on the point which Mr. Pickles raises as to the necessity of the "no trespass" sign?

President Morrow (from the floor): I think there are a great many times when there is use for a "no trespass" sign. I think we ought to have a plan for one and a standard for one, for those to use it who may see fit to do so.

Vice-President Fanning: Any further discussion? If not, we will vote on the adoption of this material for the Manual.

(The motion was put to a vote and carried.)

Mr. Drumeller: This committee was also assigned the subject, Close-Clearance Sign, with a view to the adoption of a suitable sign for scant clearance. The report is not very long. Shall I read it, Mr. Chairman?

Vice-President Fanning: Yes, if you like.

(Mr. Drumeller then read the matter under Close-Clearance Signs on pages 538 and 539.)

Mr. Drumeller: We may also add that this sign as indicated in Figs. B and C, is similar to the sign adopted by the Iowa State Commerce Commission on December 10, 1935. This report is offered as information.

Vice-President Fanning: Is there any discussion? If not, it will be so received.

Chairman Botts: The tenth assignment is Ballast; Develop relationship of ballast materials between service behavior and results obtained by Los Angeles testing machine. The committee reports progress. Under Ballast, Section design, a recommendation for publication in the Manual will be presented by Mr Kennedy, chairman of the subcommittee.

Mr. A. D. Kennedy (Atchison, Topeka & Santa Fe): The ballast section which the committee presents for adoption and inclusion in the Manual will be found on page 540. Sections No. 1—Curves and No. 2—Curves are recommended for superelevations up to and including three inches. Sections 1-A—Curves and 2-A—Curves are recommended for superelevations in excess of three inches. These sections are an adaptation to curved track of the sections that were adopted last year, and I move their adoption and inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Kennedy: It is hoped that next year we will be able to present the sections for materials with crushed particles of less than 20 percent.

Chairman Botts: On Assignment 11, Investigate the use of asphalt in ballast, a progress report will be presented by Mr. Podmore, chairman of the subcommittee.

Mr. J. M. Podmore (New York Central): This report is shown on page 540, Appendix F, Investigate the use of asphalt in ballast. This is a new assignment for the committee, and I believe it is the first time asphalt has been suggested for use in ballast. I will read the most important paragraphs of the report.

(He read the second, third and fifth paragraphs of the report.)

Mr. Podmore: Suggested Specifications; These are practically the same as used by the Ohio State Highway Department, and I will not read them.

(Following this statement, he read a number of the paragraphs under "Methods of Application" and offered the report as information.)

Vice-President Fanning: This is a suggestion for an experiment, as I understand it. I will be glad to hear any comments anyone desires to make from the floor. If not, we will receive the report as information.

Chairman Botts: On the twelfth assignment, Revision of the Manual, the committee has no report to make other than the additions and revisions that have previously been approved today. That completes the report of this committee.

Vice-President Fanning: This is the first report of the combined Roadway and Ballast Committee, and I should like to use all of the best adjectives that we have in the book up here, in telling you about it, but I am embarrassed in doing so because this is my gang, so all I have to do is to thank you, Mr. Botts, and you gentlemen on behalf of the Association. You are excused. (Applause).

DISCUSSION ON IMPACT

(For Report, see page 362)

President Morrow: I do not intend to call the Special Committee on Impact to the platform, but I wish to state that the work of this committee is dependent upon providing the funds for some additional research work. So far we have not been able to make those funds available. The committee, however, while it is inactive pending the securing of such funds, is continued so as to have it available if and when we can secure the necessary funds for the work which it is to do. I wish to say that in explanation of the apparent inactivity of the committee.

DISCUSSION ON WATER SERVICE, FIRE PROTECTION AND SANITATION

(For Report, see pp. 219–247)

(Vice-President Fanning presiding.)

Chairman B. W. DeGeer (Great Northern): Your committee has no report or recommendation at this time on Subject No. 1, Revision of Manual. The final report on Subject No. 2, Types of tannins used in water treatment, will be presented by the chairman of the subcommittee, Mr. R. M. Stimmel.

Mr. R. M. Stimmel (New York, Chicago & St. Louis): The report of Subcommittee 2 is on pages 220 to 222.

Although tannins have been used for several years in water treatment, supplementing soda ash and other water treating chemicals, there has been considerable confusion in the use of the word "tannin". The term "tannins" is frequently used as synonymous with tannic acid, but it is more properly a class name for astringent plant products which have certain characteristic color reactions and properties.

Tannin is present in the woody tissue of numerous plants, of which the higher seed plants and particularly trees, are the most important commercially. The tannin is extracted from wood by various solvents, most frequently by hot water. The extract is then concentrated to a viscous liquid or solid. The tannins used in water treatment are nearly always in the form of extracts.

Chemically, tannins are complex ring compounds, the exact composition of which is not known. For this reason, tannins are identified by their reactions rather than by their structure. Based on these reactions, tannins are divided into three groups, two of which, depside and phlobatannins, are considered in the report. The depside tannins, which give a blue black color with iron salts, include among others those from chestnut wood, oak wood and sumac, as well as ordinary tannin. The principal phlobatannins are hemlock extract, chestnut oak extract, quebracho and cutch.

For some purposes the group properties are important. Generally, however, the reactions of the individual tannin extract should be considered in using such material, because of differences in constitution and also because of differences in impurities present. Therefore, general instructions covering the selection of the type most suitable under various conditions cannot be given at the present time.

Your committee will no doubt present additional information on this subject as it becomes available. The report is submitted as information.

Vice-President Fanning: Is there any discussion? If not, the report will be received as information.

Chairman DeGeer: A progress report on Subject 3, Cause of and remedy for pitting and corrosion of locomotive tubes and sheets, with special reference to the status of embrittlement investigations, will be presented by the chairman of the subcommittee, Mr. R. E. Coughlan.

Mr. R. E. Coughlan (Chicago & North Western): The report of this subcommittee appears on page 73 of Bulletin 404 (June-July, 1938) and as Appendix B on page 222 of the committee's report.

During the past year your committee, working with the research engineers of the U. S. Bureau of Mines, has endeavored to bring the reports of this research work up to date so that this information would be available in our own publications. Supplementing the report in Bulletin 404, the committee report outlines methods of treatment using the tryosin reagent and a method of testing to determine lignin in steam boilers.

These reports are offered as information.

Vice-President Fanning: Any discussion? They will be received as information.

Chairman DeGeer: The progress report on Subject 4, Value of water treatment, will be presented by Mr. C. R. Knowles, chairman of the subcommittee, while Mr. W. L. Curtiss will present a monograph on this subject.

Mr. C. R. Knowles (Illinois Central): The report of Subcommittee 4 appears on page 224.

The committee has done considerable work on this subject and has collected a lot of data during the past year. Through the courtesy of the manufacturers of boiler feedwater treatment, work is being done to determine the ratio of scale deposit to the total hardness of certain waters and the influence that the sulphate-carbonate ratio may have on the deposit of scale. These studies are not complete, and this year's report is confined to a review which provides an historical background for the monograph which Mr. Curtiss will present. This report is submitted as information.

Vice-President Fanning: We will hear Mr. Curtiss.

Mr. W. L. Curtiss (New York Central): This monograph is found on pages 227 to 231, with the title, Value of Water Treatment.

An investigation was begun in 1924 by the New York Central to determine if it would be economical and desirable to initiate an extensive program of water treatment for locomotives. It was realized at the outset that the first and most important thing to be determined was how much loss to the railroad is occasioned by bad water, as a measure of the value of the water treatment proposed.

Your committee concluded in 1924, as reported to the Association, that for each pound of incrusting solids that entered a locomotive boiler, the loss to the railroad would amount to at least 13 cents, but it was decided to make an independent study of the New York Central's specific conditions and records to determine, if possible, the actual loss from the use of bad water, without resort to the above 13-cent formula.

For comparative purposes, four districts were selected in which, during 1923, there was little or no overlapping of locomotive runs. The waters used in these districts were quite different in incrusting properties, ranging from very soft water on the Boston & Albany to very hard water on the Ohio Central Lines.

From an analysis of every supply and the quantity used, the total pounds of incrusting solids entering the locomotive boilers in each district was determined. Data were collected for the locomotive mileage, boiler repair cost and cost of fuel for 1923. These data are set forth and tabulated in this report in such form as to show to what extent the cost of repairs and fuel was greater where the incrusting solids were greater.

By a few simple calculations of these factors, a comparison was developed between what the increase in costs should be if determined by the 13-cent factor per pound of additional incrustants and what the actual increase was, and it was found in every case in comparing the four districts that the actual increase was somewhat greater than that determined by the 13-cent factor. Therefore, it was concluded that in the case of the New York Central for the year 1923, the facts presented support the AREA formula to a degree that is remarkable and also indicate that the formula is conservative.

This report is offered as information.

Vice-President Fanning: Is there any discussion? If not, it will be so received.

Chairman DeGeer: The committee has no report on Subject 5, Regulations pertaining to railway sanitation. The final report on Subject 6, Hose pipes or nozzles—types and uses, will be presented by Mr. W. A. Radspinner, chairman of the subcommittee.

Mr. W. A. Radspinner (Chesapeake & Ohio): The report is printed on pages 232 to 240. Your committee has selected various types of equipment used in modern fire fighting and has stated the purpose for which it can be used by railroads. In order to cope with the increase in heights of buildings and the use of various hazardous materials, many different types of play pipes have been and are being developed. Recently water mist has been used effectively on oil fires, as described in the paragraph covering Fig. 10. Freeman's fire-stream tables, on pages 238 and 239, show the pressure at the nozzle required to obtain effective fire streams of various quantities, heights and distance, with a 2½ in. standard fire hose and the standard Underwriters' nozzle. Similar information is shown graphically in Fig. 12. This report is submitted as information.

Chairman DeGeer: The final report on Subject 7, Trucks for use by water service maintenance forces, will be presented by the chairman of the subcommittee, Mr. J. P. Hanley.

Mr. J. P. Hanley (Illinois Central): The report appears on page 240. Since the curtailment of local freight and passenger train schedules and the construction of paved highways, the use of commercial trucks by maintenance of way forces, including water service men has attained considerable proportions and will no doubt increase.

A summary of replies received from a questionnaire sent to the water service engineers of this committee appears on page 241 and indicates that the majority opinion favors small trucks for water service maintenance. An estimate showing the approximate annual cost of operating a ½-ton truck which would be suitable for this class of service appears at the bottom of this page.

The conclusions that appear on page 242 summarize the reasons why the committee favors the use of this equipment for water service men at locations where other means of transportation are not available or economical. I would like to express the appreciation of the committee for the cordial co-operation received from Committee 27—Maintenance of Way Work Equipment in preparing this report. The report is submitted as information.

Vice-President Fanning: Is there any discussion? It will be so received.

Chairman DeGeer: Your committee has no report on Subject No. 8, Conditioning water for vapor boilers on streamliners and Diesel units. The final report on Subject No. 9, Methods for checking and handling the control of locomotive blowdowns, will be presented by Mr. J. B. Wesley, chairman of the subcommittee.

Mr. J. B. Wesley (Missouri Pacific): The report of subcommittee 9 on page 243, divides the subject matter into what we consider to be its most important elements. Under Supervision, it is shown that much preliminary work should be done by the water chemist to determine the total amount of substance dissolved in the water used and at what critical point foaming can be expected to take place. He must also calculate the percentage of water that must be blown out to keep the concentration below this critical point so that foaming will not take place. The samples from the boiler must be taken with care to insure that they are representative. Tests can be made with any one of several instruments, none of which, so far as we have been able to determine, excels the others in accuracy and convenience under all other conditions.

Blowing on the road can be accomplished by means of different valve arrangements, but personal attention by the engine crew is desirable under all operating conditions. The most desirable means of disposing of the boiler discharge seems to be through the centrifuge type of muffler. There is no completely automatic facility that will blow the boilers satisfactorily, and it is not possible to set up detailed and complete instructions for the blowing. Because of variations in operating conditions from time to time or day to day, it is necessary that the enginemen and firemen be allowed to use their own judgment as to what blowing is required. This is a final report submitted as information.

Vice-President Fanning: Any discussion? It will be so received.

Chairman DeGeer: This completes the report of Committee 13.

Vice-President Fanning: This has been an excellent report, and the committee is excused with the thanks of the Association. (Applause.)

DISCUSSION ON YARDS AND TERMINALS

(For Report, see pp. 249–283)

(President Morrow presiding.)

Chairman Hadley Baldwin (New York Central Lines): Our first report will be that on Assignment 1, Revision of Manual, which will be presented by Mr. Lyford, chairman of the subcommittee.

Mr. L. L. Lyford (Illinois Central): This report recommends certain changes in Manual material that is in Section 2411 on page 14–11 of the Manual. Due to changes in the use of moving stairways, increased uses, and so forth, particularly at station platforms, it is desirable to make some change in the present Manual material, also to minimize the use of the word "escalator" which is a copyrighted term used by a certain manufacturer.

(Mr. Lyford read all of the matter appearing below the first paragraph in Appendix A, pages 249 and 250.)

Mr. Lyford: I move that this wording be substituted for that now in the Manual.

(The motion was seconded.)

Mr. Geo. S. Fanning (Erie): I should like to ask why you leave "or escalators" in paragraph (e).

Mr. Lyford: The idea was to have it mentioned here but to minimize its use.

Mr. Fanning: What is the difference between a moving stairway and an escalator? You say "a moving stairway or escalator."

Mr. Lyford: "Moving stairway" is the general term. The word "escalator" is used by a particular manufacturer to designate a moving stairway.

(The motion was then put to a vote and carried.)

Chairman Baldwin: Our next report is on Assignment 4, Scales used in railway service. This will be presented by Mr. Harrison, chairman of that subcommittee.

Mr. M. J. J. Harrison (Pennsylvania): Your committee presents at this time, beginning on page 251 and extending through to one paragraph near the top of 267, material under the heading "Specifications for the Manufacture and Installation of Two-Section, Knife-Edge Railway Track Scales". Similar material was submitted to the 1927 convention and there adopted. With the passage of time, your committee has studied this 1927 material. In 1937 it submitted as information a proposed revision of that material which is now further revised and submitted as Manual material in place of the material adopted in 1927. The material here proposed for such adoption, consisting of 27 sections, differs principally in editorial form and, to some extent, in technical detail from that in the Manual. The editorial form has been changed to conform with other material of this same nature in the Manual, to make for consistency.

(Mr. Harrison then read each of the section headings in turn.)

Mr. Harrison: I move that the material so hastily outlined, be adopted to replace material now in the Manual under the same title.

(The motion was seconded, put to a vote and carried.)

Mr. Harrison: At this time your committee proposes, on page 267, three minor revisions of present Manual material, under the heading "Specifications for the Manufacture and Installation of Motor Truck, Built-In, Self-Contained and Portable Scales for Railway Service." This material was adopted in 1936. The revisions here proposed are suggested because certain questions had been referred to the committee for interpretation, and your committee felt that this indicated that the specifications needed clarification. The first revision proposed is on page 14–90 of the Manual and is an amplification of the definition of one of the symbols of the formula, being the width of tire in feet. It is proposed to add to this definition the words "or the permissible wheel loads in pounds, divided by 12,000" which, in most jurisdictions, on account of legal limitations, results in the same thing, as far as those loading assumptions are concerned. In certain other jurisdictions it will result in a somewhat restricted load value but one which is more consistent with the legal requirements. The second one, dealing with an item on page 14–92 of the Manual, is likewise proposed for the purpose of clarifying the specification. The wording is: "For the design of motor truck scales, the live load shall be assumed to be a five-axled vehicle whose wheel gage, axle spacing and axle loadings are as shown in Table 1408."

It is proposed to add to that wording the following: "For the general purposes of design, the vehicle shall be assumed to be positioned with its longitudinal axis between the weighbridge girders and parallel to the longitudinal center line of the scale, with one series of wheels in the vertical plane through the web of one weighbridge girder. For the end and corner reactions, one rear wheel shall be assumed over the center of a

main loading bearing. No lateral or longitudinal distribution of the wheel loads shall be assumed."

The third proposal has to do with an item on page 14–101 and is, again, an amplification. The present wording is: "Scale foundations resting upon or extending into the ground shall be constructed of concrete. (See Paragraph 515.)" It is proposed to add to this paragraph the following: "The quality of materials and methods of mixing and placing the concrete shall conform to the specifications of the American Railway Engineering Association for Class A concrete." I move the adoption of the three revisions just read.

(The motion was seconded, put to a vote and carried.)

Chairman Baldwin: The next report is on Assignment 5, Bibliography on subjects pertaining to yards and terminals appearing in current periodicals. The substance of this report, Appendix C, speaks for itself, but it does not indicate one thing which I would like to express at this time, and that is the appreciation of your committee of the work of the author in this comprehensive assembly of references, and Mr. Tratman is singly responsible for it. He is certainly much valued by the committee, not only on this account but because of his critical comment of the work of the committee.

Our next report is on Assignment 6, Substitution of outlying yards and facilities for yards and other large facilities in cities where land values are high. This report will be presented by Mr. Giles, chairman of the subcommittee.

Mr. W. H. Giles (Missouri Pacific): The report of Subcommittee 6 begins on page 280, and summarizes in a general way information contained in replies to a questionnaire submitted to 69 railways in this country and Canada. Under the existing conditions, it is appreciated that any large expansion of terminal facilities of the kind to which this report is addressed would be a rare occasion at this time. However, it is hoped that this situation will improve to the extent that we can expect normal conditions to return in the future, and our consideration of the problem is based upon such expectation.

This report has been made to identify the various factors of design and operating methods that deserve analysis and evaluation when considering terminal improvement of this nature, and it is submitted as information pending further study of the relative significance of these factors and, if possible, determining for each its relative rate and the extent to which its application is pertinent and practical in arriving at a wise conclusion in any case. The committee solicits your constructive suggestions.

President Morrow: Is there any discussion of this report? If not, it will be received as information.

Chairman Baldwin: The next report is on Assignment 7, Classification yards. This report will be presented by Mr. Hand, chairman of the subcommittee.

Mr. G. F. Hand (New York, New Haven & Hartford): The report of the subcommittee will be found in Appendix E, page 282. This committee has collaborated with the Committee on Economics of Railway Location and Operation, and has been advised that the things we have set up in this year's report do not affect any of the studies of Committee 16. It has been the custom of the subcommittee in past years to make studies of different parts of classification yards. That idea has been carried out this year and will be continued in succeeding years, picking different features of classification yards for special study. This year we have attacked the hump end of the receiving yard. You will find at the bottom of page 283 a summary of the principles which are discussed in the preceding matter. The report speaks for itself. It is one of progress and is offered as information.

President Morrow: Any discussion of this report? If not, it will be received as information.

Chairman Baldwin: The committee has no report to make at this time on Assignment 2, Arrangement of tracks and facilities for passenger stations and engine terminals required to meet the demands of internal combustion and electric locomotives; on Assignment 3, Auxiliary yard facilities and appurtenances, and on Assignment 8, Adaptation of enginehouses, shops and engine terminal layouts for handling oil-electric locomotives and rail cars. That completes the report of Committee 14.

President Morrow: Mr. Chairman, I want to express the appreciation of the Association for this most excellent report and you are excused with the thanks of the Association. (Applause).

DISCUSSION ON RAIL

(For Report, see pp. 593–624)

(President Morrow presiding.)

Chairman John V. Neubert (New York Central): I regret to inform you that the Rail committee lost four members through death, Mr. Herbert Clarke of the D. & H., Mr. Morrill of the Boston & Maine, Mr. Young of the Reading, and, since our report was printed, Mr. Backus of the Illinois Central. Brief obituary statements on the first three appear on pages 594 and 595. Mr. Backus was employed for many years on the Illinois Central. He became a member of this Association in February, 1920; was a member of Committee 12—Rules and Organization, continuously since 1925, and became a member of this committee in March, 1936. Also on page 594, we refer to the death of Mr. Bahls, one of Mr. Penfield's assistants who did some outstanding work in connection with the revision of the Manual.

The report on Revision of Manual will be presented by Mr. Yager.

Mr. Louis Yager (Northern Pacific): The first subject deals with the revision of Specifications for Heat Treated Carbon Steel—Alloy Steel Track Bolts as found in the 1936 Manual 4–29. This revision is made for the purpose of clarification and so that our specification may conform with the ASTM. As you probably know, that specification is the joint work of the ASTM and our committee. I will read the proposed change:

"The steel for the nuts shall conform to resulphurized nut stock grade of the ASTM specifications for commercial quality, hot-rolled bar steel, Serial Designation A–107, latest issue."

It is our purpose to follow the current specifications of the ASTM in respect to nut steel.

The second proposal is purely one for clarification because attention is called to the fact that, as this specification now reads, some bolts may be rejected because the nut may strip below the elastic limit of that particular bolt, when it is clearly the intention that the elastic limit be that outlined in the specification. The proposal therefore reads:

"The threads of the nut shall not 'strip' when the bolt, with the nut fully mounted, is tested in tension to the minimum yield point specified in Section 6(a) for the grade ordered, based on the theoretical area at the root of the thread, the load being applied to the head of the bolt and the bearing side of the nut."

I move that these two revisions be made of the specifications now appearing in the Manual.

(The motion was regularly seconded, put to a vote and carried.)

Mr. Yager: The next deals with a revision which is to include the so-called Every-Ingot Nick and Break Test. Under the existing specifications, we have three test pieces

broken to determine the X-Rayls of the heat. Under the proposed revision there would be a nick and break test representing every top rail of every ingot of each heat.

This specification has been considered with the members of the technical committee of rail manufacturers, who have signified that they are willing to approve that revision without any change in the base price for steel rail.

This revision affects several sections of the specifications: First, 302. Elongation and Permanent Set; next, 303. Interior Condition. I don't believe it is necessary to read these, but wish to call your attention to the fact that in the revision a test piece will be taken representing the top rail of every ingot, and that will be broken and examined for the defects which classify the rail as an X-Rayl.

This revision is desirable because it gives us an accurate index of every "A" rail, in that a test piece from every "A" rail is examined, as contrasted with the present practice of testing three rails out of every heat. Of course, as is to be expected, the three rails are not necessarily representative of the entire heat. An investigation which we made indicates that the number of X-Rayls that will likely be designated as such will be approximately one-half of the designation under the present specification.

Mr. President, the committee moves that the revision outlined in Sections 302 and 303 be approved and substituted for the present sections in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Yager: The Rail committee was requested by a number of railroads to make a recommendation on an issue dealing with slotting and beveling of the ends of rail. A number of plans have been submitted, and they differ very slightly. We found that this same matter was handled by the Track committee, which made a recommendation for frogs and switches that was approved by the convention in 1938. That is shown in the Track Committee's Plan No. 140, which provides a horizontal back cut of 1/16 in. and a depth of 1/8 in. The committee recommends that that plan be adopted for beveling and slotting of rail ends in general, and I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Yager: The next item refers to Plan No. 411-Joint Bar and Assembly for 112-lb. R. E. rail and, likewise, Plan 412 which is a similar assembly for 131-lb. R.E. rail. The spiking that is shown in that assembly was used because at that time there was belief that it was necessary to use the back of the spike as shown to avoid some possible patent complications. Recently the matter was thoroughly investigated by patent counsel, and the conclusion developed that there are no patent complications. That has led us to present to you the recommendation, that the following notation be added to these plans, reading: "Spike may be driven as shown, or reverse". I move its adoption for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Yager: That concludes the report of the subcommittee.

Chairman Neubert: The next item is Appendix B, Further research, including details of mill practice and manufacture as they affect rail quality and rail failures. I am chairman of this subcommittee, which is a contact committee with the rail manufacturers in connection with the research and investigation carried on under Dr. Moore at the University of Illinois. To save time and possibly, confusion, we will proceed as we did last year. After the committee's report has been presented, Dr. Moore will review the work carried on under his direction, including the assignment covered in Appendix B, as well as his work on the cause and prevention of rail battering. This research work is sponsored jointly by the Association of American Railroads and the rail manufacturers, each paying one-half of the expense.

A report on research work relating to the continuous welding of rails, which is sponsored entirely by the Association of American Railroads, will also be included in Dr. Moore's remarks. A report on tests of joint bars, one of the assignments to this committee, will be incorporated in the address which Dr. Talbot will present immediately after this committee leaves the platform.

We will proceed to the various statistical reports, transverse fissure failures, and so forth, by Mr. W. C. Barnes.

Mr. W. C. Barnes (American Railway Engineering Association): The rail failure statistics for 1937, page 600, include failures of all types reported to December 31, 1937, inclusive, in 2,131,730 tons of rail rolled from 1932 to 1936, inclusive.

Table 1 on page 601 shows the five-year average failure rate of the 1932 rollings, from the date rolled to December 31, 1937, to be 64.1 per 100 track miles. This is a very good five-year average, compared with the previous rollings, as is evident from Fig. 1 on page 602. The mill rating charts, Figs. 3 and 4, for the general rail failures, which appear on pages 604 and 605, require no special comment.

This report is submitted as information.

President Morrow: It will be so received.

Mr. Barnes: The transverse fissure failure statistics appearing on pages 606 to 612 constitute a cumulative record of transverse fissure failures which have occurred in all rollings from all mills up to and including December 31, 1937.

There has been a marked annual increase since 1933 in the service as well as in the detected failures reported, as shown in Fig. 1 on page 607. For a number of years after the introduction of detector cars, we were catching up with this increase and halting it, but it is now running away from us.

Comparing failures in 1937 with those in 1936 (see page 606) we find that the service failures increased 18.6 percent despite an increase of 20.1 percent in detected failures. The service plus detected total increased 19-1/2 percent, or an increase of 2,929 failures.

The total fissure failures reported in 1937, as shown on insert table No. 1, were 7,024 service and 10,955 detected, or a grand total of 17,979 fissure failures in one year.

The charts of fissure failure rates on pages 611 and 612 have been revised to include a longer period of observation than in former reports. They show very good records for all of the rollings listed, for practically all of the mills. Those mills that are not quite so good have made a decided improvement in the latter years.

This report is submitted as information.

President Morrow: It will be so received.

Mr. Barnes: The controlled cooled and Brunorized rail data shown on page 613 include the contract tonnages, somewhat incompletely reported, laid prior to June 30, 1938.

A total of 1,048,718 tons of controlled cooled rail and 47,300 tons of Brunorized rail is shown in Table 1 on page 613. Additional and supplementary reports since received have increased these totals to 1,200,030 tons of controlled cooled and 60,863 tons of Brunorized rail. No transverse fissure failures in this rail have been reported to date.

This report is also submitted as information.

President Morrow: It will be so received.

Mr. Barnes: On top of page 614 there is a short paragraph referring to the AAR detector car work which is continuing.

There is hardly anything to add except that the increasing prevalence of tranverse fissures as reported in the transverse fissure statistics in recent years is being paralleled by an increasing number of fissures detected per mile tested.

The report is submitted as information.

President Morrow: It will be so received.

Chairman Neubert: Appendix F, Cause and prevention of rail battering, and so forth, will be presented by Mr. Graham.

Mr. F. M. Graham (Pennsylvania): The assignment, cause and prevention of rail battering and methods of reconditioning rail ends, fastenings, and frogs in track, is being handled in co-operation with the Rails Investigation at the University of Illinois. Laboratory work has been proceeding continuously for a long time, but the efforts of this particular subcommittee have been somewhat hampered by difficulty in arranging for a field test where the different methods of hardening rail ends can be compared. Such a test, however, is now quite fully lined up, and the laying of the rail, together with the hardening of rail ends to be done by field methods, will be undertaken about the first of next month.

The test will include four stretches of 100 joints each, hardened by each of four mill methods. There will also be four stretches of 100 joints each hardened by different field methods, and including, in addition, 100 joints that will not be hardened, as a yardstick in making comparisons. This work will be undertaken on the Chesapeake & Ohio Railroad in a territory where very nearly 40 million tons of gross tonnage pass over the track per year, which should give us rather early information as to the comparative merits of different methods.

It is possible some of you may care to see the work, which will include the field hardening and the laying of the mill-hardened rail. This is presented as a progress report, and we recommend that the subject be continued.

President Morrow: It will be so received.

Chairman Neubert: Appendix G, Economic value of different sizes of rail. Mr. Farrin of the Illinois Central is chairman. This is a progress report on which we have nothing to report so far this year, and I won't take the time to have him come forward.

Appendix H, Economics of rail lengths in excess of 39 ft. In the absence of Mr. Reece, the report will be presented by Mr. Magee.

Mr. G. M. Magee (Association of American Railroads): The report of Subcommittee 6 having the assignment, Economics of rail lengths in excess of 39 feet appears on pages 615 to 620, inclusive.

On pages 616, 617 and 618, a statement is given of the calculated economic benefits of 39-ft., 45-ft., and 78-ft. rail lengths for both 112-lb. and 131-lb. rail. These calculations have necessarily been prepared for typical track and traffic conditions, and it should not be expected that they will exactly reflect the savings on each individual railway. It is thought, however, that they are of value as a guide to judgment in studying this problem.

The savings to result from the use of 45-ft. and 78-ft. rail, compared with 39-ft., have been capitalized at 5 percent and expressed as the added cost per ton to which the savings are equal on that basis.

For 112-lb. rail not end-hardened, the net benefits are calculated to be $1.85 per gross ton of rail purchased for the 45 ft. length, and $6.82 per gross ton for the 78-ft. length. For 131-lb. rail not end-hardened, the net benefits for the 45-ft. length are estimated at $1.62 per gross ton, and $6.01 for the 78-ft. length.

For end-hardened rail, the estimated net benefits are as follows:

45-ft. 112-lb. rail	$1.55 per gross ton
45-ft. 131-lb. rail	1.39 per gross ton
78-ft. 112-lb. rail	5.77 per gross ton
78-ft. 131-lb. rail	5.13 per gross ton

Replies to a questionnaire to develop the preference for standard rail length are summarized as follows:

Rail Length Favored	*Percentage of Mileage Canvassed*
39 ft.	6.5
45 ft.	13.9
50 ft.	7.4
78 ft. or longer	24.7
No recommendation	22.7
Total	75.3

These figures are based on replies that represent 199,454 road miles of railway.

The subcommittee believes that the economics of 45-ft. and 78-ft. rail have been developed to the extent that present data make possible. The report is presented as information with the recommendation that the subject be discontinued.

President Morrow: It will be so received.

Chairman Neubert: Appendix I, Continuous welding of rail, will be presented by Mr. J. C. Patterson.

Mr. J. C. Patterson (Erie): This report will be found on page 620.

(Mr. Patterson read all of Appendix I, which was offered as a progress report.)

President Morrow: It will be so received.

Chairman Neubert: Appendix J, Service tests of various types of joint bars, will be presented by Mr. Faries.

Mr. Robert Faries (Pennsylvania): The subcommittee report on Service tests of various types of joint bars will be found on pages 621 and 622. I will not read it for the reason that Dr. Talbot will later cover in considerable detail the subject matter that is presented. The report is submitted as a progress report, with the recommendation that the subject be continued.

President Morrow: It will be so received.

Chairman Neubert: The next is Appendix K, Investigate the advisability of straightening bent and kinked rail for reuse in main line, Mr. Bronson.

Mr. C. B. Bronson (New York Central): This is given as a final report, but that does not necessarily mean that the subject is concluded by any means.

We all realize that this is a subject of intense importance on account of high-speed operation. However, the subject as assigned to this committee covers a restricted field, that is, "Investigate the advisability of straightening bent and kinked rail for reuse in main line." The subject appeared somewhat ambiguous as we started work on it and, after consideration, we finally decided that a sharp distinction should be made between a bent rail and a kinked rail.

A bent rail, in our opinion, is the so-called surface-bent type, with which we are all familiar. A kinked rail would be in the category of a rail that was damaged by improper counterbalancing—the type where it is bent inward and downward, the web is distorted and the flange is distorted in the reverse direction.

In order to determine what the practice was on the various roads, the committee sent out a questionnaire and found that apparently very little is being done in the way of straightening bent rails. The principal method being used was the prosaic method of taking the rails in and gagging them as is done at the rail mills. However, some field equipment was developed to do the same work. Investigations were made in the field and we found that, instead of taking the driver kinks out of the rail, it was a question of ironing the rails out on account of surface bent conditions. The physical aspect or

damage, of course, was the most important thing to determine. So, we delved into the literature and gathered as much information as we could as to what actual damage was done to rail by the methods of overstressing.

We arrived at the conclusion, after studying all the available data, that the physical damage was not serious. The subcommittee then found there was no further field of investigation directly under its assignment, and arrived at definite conclusions which are as follows:

(Mr. Bronson read the conclusions on page 623.)

Mr. Bronson: I might add, in conjunction with this, that Dr. Moore has started a series of tests under the Rails Investigation at the University of Illinois to gather further data on possible physical distortion and damage done to rails that have been badly overstressed or kinked, or which suffered the equivalent of kinking.

This is submitted as information, and it is recommended that the subject be discontinued.

President Morrow: It will be so received.

Chairman Neubert: Appendix L, Specifications for relayer rail. In the absence of Mr. Oviatt, we will hear from Mr. Penfield.

Mr. W. H. Penfield (Chicago, Milwaukee, St. Paul & Pacific): This report, Appendix L, Specifications for relayer rail, is found on page 624.

(Mr. Penfield read the report found under Appendix L.)

Mr. Penfield: This is submitted as a final report, and it is recommended that the subject be discontinued. I move that the recommendation of the committee for the elimination of the present Manual material be approved.

(The motion was duly seconded, put to a vote and carried.)

(At this point Mr. Neubert introduced Dr. Moore, who presented the address which served as the basis for the reports appearing on page 655 to 713, inclusive.)

Chairman Neubert: Mr. President, unless, there are some questions or discussion, that completes our report.

DISCUSSION ON WATERWAYS AND HARBORS

(For Report, see pp. 285–290)

(Vice-President Fanning presiding).

Chairman G. P. Palmer (Baltimore & Ohio Chicago Terminal): The committee offers a small minor revision in the Manual which will be presented by the subcommittee chairman, Mr. E. H. Roth.

Mr. E. H. Roth (Norfolk & Western): Our committee recommends a very minor change in the Principles appearing in the Manual on page 25–13, these revisions being confined to the addition of the words underlined and the deletion of "bridging" in the first line of paragraph 1 under Allocation of Expense for the Construction, Maintenance and Operation of Bridges over Navigable Waterways.

I move the adoption of the changes as printed on pages 285 and 286.

(The motion was duly seconded, put to a vote and carried.)

Chairman Palmer: The committee has prepared as part of Subject 3 a report covering coal piers and other piers. This report will be presented by Mr. Swatosh, chairman of the subcommittee.

Mr. W. R. Swatosh (Erie): The report of subcommittee 3 on coal piers is shown as Appendix B, pages 286 to 290. It covers only the general features encountered in the design and construction of coal piers, and is presented as information.

Vice-President Fanning: Unless there is discussion, it will be so received.

Chairman Palmer: This will conclude the report of the Committee on Waterways and Harbors for this year.

Vice-President Fanning: Mr. Chairman, this committee is to be complimented on an excellent report, and it is excused with the thanks of the Association. (Applause).

DISCUSSION ON RECORDS AND ACCOUNTS

(For Report, see pp. 435–456)

(Vice-President Fanning presiding.)

Chairman C. A. Knowles (Chesapeake & Ohio): The committee was assigned eight subjects for study during the past year. Of these eight subjects the committee reports progress only in respect to two, namely: 1, Revision of Manual, and 5, Construction reports and records.

Subject 2, is Bibliography on subjects pertaining to records and accounts. The report thereof, in the absence of the subcommittee chairman, Mr. Weymouth, will be presented by Mr. Braden.

Mr. E. V. Braden (Pittsburgh, Chartiers & Youghiogheny): The report will be found in Appendix A, page 436. The method followed in compiling this bibliography for the current year was similar to that of previous years. The list of books and periodicals pertaining to records and accounts is submitted with an explanatory note which might be helpful in deciding whether the subject of the article is available for your particular use.

Vice-President Fanning: Is there any discussion on this? If not, the report will be received as information.

Chairman Knowles: The next subject is No. 3, Office and drafting room practices, and the report will be presented by the chairman of the subcommittee, Mr. D. C. Teal.

Mr. D. C. Teal (Chesapeake & Ohio): This report appears as Appendix B. Of the six subjects assigned for the past year, only three have been fully completed. Your committee reports progress on the others and expects to complete them next year.

The three subjects reported on here are: Methods of reproducing drawings; Reduction and enlargement of drawings, and Methods of folding and punching drawings.

In order to establish prevailing methods, the committee submitted a questionnaire to 58 of the Class I railroads. In general, the data presented here represent information obtained through this medium and the practices recommended are those indicated by a plurality of users.

The report on Methods of reproducing drawings divides reproduction methods into three general processes. The first of these, light-exposure printing, is defined as exposing sensitized paper or cloth to white light through a negative, which is usually a tracing, and then developing the exposed paper in water or chemicals. Under the heading "Analysis" the uses and advantages of light-exposure printing are discussed in detail. Blueprinting is usually the least expensive and most commonly used light-exposure method.

The photostatic process is defined as photographs made directly upon the surface of prepared paper by means of a special photostat camera. Its uses, advantages and disadvantages are pointed out in the analysis.

Photo-lithographic (planograph) process reproductions are defined as those printed from metal plates which, in turn, are etched from special photographs of the subject matter. The uses and limitations of this method are discussed.

The approximate unit costs for making the various kinds of reproductions are given in the report as a matter for consideration when selecting the proper one to use. In concluding this subject, your committee recommends that, in general:

1. Light-exposure printing is best suited for reproduction of construction work plans.

2. Photostatic reproduction is acceptable and usually the most convenient for making copies of plans or exhibits for attachment to agreements or other legal documents.

3. The photo-lithographic or planograph process is the best suited and most economical method for making copies of standard drawings and specifications in large quantities.

The subject, Reduction and enlargement of drawings, begins on page 442. An analysis of the three principal methods used, together with advantages and limitations of each are discussed in detail. In concluding this subject, your committee recommended that, in general:

1. When the reduced or enlarged plan is to be used for design or layout work where accurate measurements are important, it should be replatted by hand, using a scale and proportional dividers, or the pantograph machine should be used.

2. When reductions or enlargements are desired for exhibit purposes, the faster and more economical photostatic method should be used.

The report on Methods of folding and punching drawings begins on page 444. Two accepted methods of folding drawings to letterhead size are described and illustrated. The top-binding style (Fig. 1) is recommended for legal document appendages and can be used for drawings that are to be attached to correspondence files. The side-binding method (Fig. 2) is usually mandatory for drawings that are to be included in bound reports. This method is also suitable for correspondence files. Fig. 3 on page 447 illustrates a convenient method of folding right-of-way maps for storage in office filing cabinets.

It was found impractical to make any recommendation regarding the punching of drawings. This concludes the report on Office and drafting room practice. The material is offered as information.

Vice-President Fanning: Is there any discussion on the subject?

Mr. V. J. Bedell (New Orleans Public Belt Railroad): I wish to call attention to the last paragraph (No. 3) on page 438. I think that is slightly in error, in that colored-line prints are stated to be developed through washing in proper developing solution. Many of the colored line prints, such as ozalid, black prints "directo" and true blue are developed either by exposure to fumes or a very light application of chemicals and are not washed. It follows that the statement on page 439, second paragraph, "with the exception of slight shrinkage of paper during the developing process" is slightly in error, since those prints which are not washed do not shrink, the prints being exact reproductions of the tracings.

Vice-President Fanning: Any further discussion? If not, the report will be received as information.

Chairman Knowles: The report on the next subject, Maintenance of way reports and records, will be presented by Mr. A. T. Powell.

Mr. A. T. Powell (Grand Trunk Western): The report of this subcommittee is on page 449, Appendix C.

This year the committee has had under consideration a form for the analysis of Maintenance of Way and Structure Accounts. This form is shown on page 450 as Exhibit 1. This form allows comparison by accounts of the cost of maintaining the property expressed in terms of a dollar base of investment and a mileage basis. This comparison is to be made between divisions or systems.

This report is offered as a progress report.

Vice-President Fanning: Any discussion on this report? It will be received as information.

Chairman Knowles: The report upon the next subject, Valuation, will be presented by Mr. S. H. Barnhart, chairman of the subcommittee.

Mr. S. H. Barnhart (Norfolk & Western): The report of Subcommittee (6), Valuation, is recorded as Appendix D, on page 449.

The subjects assigned to this committee are cataloged on page 435, being four in number. On the first subject, Résumé of developments of the current year in connection with regulatory bodies and courts, I shall not burden you by reading the details as set forth on pages 449, 451 and 452.

On the second subject, designated as (b), Study of Valuation Order No. 3, reports and records, to determine if further simplifications are possible, the committee reports that substantial progress has been made in its study and investigation. There have been a number of developments since the report was written, and we hope ere long to be able to say to you that there has been substantial simplification in the requirements of reporting under Order No. 3.

The next subject, Form of Order No. 3 reports in connection with joint projects, federal-railroad, is conjoined with subject (b) and, also, we hope to be able to report soon that we have made substantial progress in setting forth the form of reports for these projects.

Subject (d), Forms for a record of ballast installations, has been a subject that we have discussed many times with bureaus of the Interstate Commerce Commission, and we again express the hope that ere long we may be able to present something that will be satisfactory to all concerned.

Vice-President Fanning: This report is offered as information. Is there any discussion on it? It will be so received.

Chairman Knowles: The report upon the next subject, Changes or revisions in I.C.C. Classification of Accounts will be presented by Mr. H. D. Barnes, chairman of the subcommittee.

Mr. H. D. Barnes (Chicago & North Western): The report of Subcommittee 7 of Committee 11 appears on pages 453 and 454.

There have been no changes in the accounting classifications subsequent to the publication of this committee's last report. The Bureau of Accounts of the Interstate Commerce Commission has, however, released three series of accounting rulings, and those involving the investment in road and equipment and other accounts used incidental to accounting for construction, maintenance and retirements are reviewed in this report.

Since this report was prepared, arrangements have been made with Mr. Bunnell, vice-president of the Association of American Railroads, whereby tentative accounting case rulings relating to investment or valuation accounting are to be submitted to this subcommittee for its consideration before they are approved. It is believed that the viewpoint of those responsible for the preparation of property records will be helpful in the consideration of these proposed rulings.

This report is submitted as information, with the recommendation that the subject be continued.

Vice-President Fanning: Is there any discussion? If not, the report will be received.

Chairman Knowles: The report upon the next subject, Methods for avoiding duplication of reports and for simplifying and co-ordinating work under the requirements of the I.C.C. and other public authorities will be presented by Mr. F. B. Baldwin, chairman of the subcommittee.

Mr. F. B. Baldwin (Atchison, Topeka & Santa Fe): The committee's report is found on pages 455 and 456.

In last year's report the committee called attention to the large number of reports of various kinds made by railroads to numerous state and federal authorities and presented a list of over 800 reports filed during 1936.

This year the committee again calls attention to this list and reports that the matter was placed before the chairman of the Interstate Commerce Commission with certain recommendations by Mr. J. J. Pelley, president of the Association of American Railroads. Two conferences with bureaus of the Interstate Commerce Commission have resulted from these recommendations. In one a committee of accounting officers conferred with the Bureau of Statistics on the statistical data required by that bureau, and in the other a committee of railroad valuation representatives discussed with the Bureau of Valuation, the possible curtailment of detail required in reports under Valuation Order No. 3.

The report is offered as information.

Vice-President Fanning: You have heard the report. Is there any discussion? If not, it will be received.

Chairman Knowles: Mr. President, that completes the report of Committee 11.

Vice-President Fanning: This is a committee that keeps us in mind of the fact that we have supervision by the Interstate Commerce Commission if we should happen to forget it. You are excused with the thanks of the Association. (Applause).

DISCUSSION ON ECONOMICS OF BRIDGES AND TRESTLES

(For Report, see pp. 372–374)

(Vice-President Hastings presiding.)

Chairman Arthur Ridgway (Denver & Rio Grande Western): The committee would like to make this a final report on this particular subject, which is the sole assignment we have had, and we feel that we have done all that can be done with it.

We would like to add to the three conclusions that are now in the Manual, two others, Nos. 4 and 5. These two conclusions will be found about the middle of page 372. I move that these be adopted and added to those that are already in the Manual.

(The motion was duly seconded, put to a vote and carried.)

Chairman Ridgway: The committee would also like to have the consent of the Association for the inclusion in the Manual of certain other material. As it now stands, if we add these two conclusions to those that are already there, we have merely some very brief statements without any of the data, reasoning, or logic leading up to those conclusions.

If you will look at the second line of the subject assigned to this committee on page 372, you will find there a phrase "under various conditions of service", and then continuing on that line, also, "with due consideration of relative influence of durability of materials and obsolescence of property." We think that was a wise insertion or expansion of the ordinary comparative economic value of this or that which so often we are asked to report on. The various conditions of service we have tried to cover under some of the additional matter not ordinarily included in a conclusion.

You will find Conclusion No. 1 subdivided with some subheadings. When we come to the obsolescence of property which, of course, is a matter of economics, we have all sorts of things that cause obsolescence of a bridge structure. For that reason, we believe that these economic conclusions that we have adopted should be preceded by

something of economic principles that would be broad enough to cover that phrase "under various conditions of service" and also obsolescence of property.

We have tried to frame these economic principles in the simplest possible form. We do not see how they can be made more brief than they appear here. We do think, however, that they cover the field of economics. None of the comittee is an economist. We do not think that there was ever such a time as the present when railway engineers are called upon to inject the matter of economics in their work on the railroads of this country.

It is unnecessary for me to read these principles. They begin on page 372 and continue to the end of the bottom of page 374. I move the adoption of these principles and their printing in the Manual.

(The motion was seconded.)

Mr. B. R. Lefiler (New York Central): What I am going to say, I do not wish to be taken as a criticism of the committee. I want to talk about the first part of these economic principles, extending from the bottom of page 372 to the top of page 373, down to the bold-faced type "Structural Values".

Several years ago, one of the most brilliant men in this country wrote a book called "Man, the Unknown". He discussed the whole field of science, and came to the conclusion that there are two classes of sciences: One class is represented by the completeness with which it can be discussed and results are predicted by mathematical methods. To that class belong most of engineering, all of astronomy, all of the wonderful science of physics, and the later developments of chemistry.

The other class contains the other remaining sciences, which he calls conjectural or pseudo-sciences. In this class, the prince of the pseudo-sciences is the science, so-called, of economics. The great scientist Soddy, a Nobel prize winner and an Englishman, came to practically the same conclusion, and he spent quite a little of his time in poking fun at the conclusions of the economists.

One principal fault of economists is their attempt to give their science a resemblance to mathematical certainty by using expressions appearing like equations. The committee has done that very thing. Let's look at this a minute. "Economy = (Value) – (Price)." What does it mean? Before you can have an equation, it must have a numerical basis. Are the words "Value" and "Price" expressible in numbers, such as 10, 20, 30, etc.?

The second equation is "Economy = (Utility) – (Cost)." Nobody has been able to define "Utility" in a strictly scientific sense, but in this set-up, it must be expressed in terms of numbers. There is no use in attempting to give a science the aspect of exactitude by resorting to mathematical expressions in stating its conclusions or results. Better leave it in the open; recognize that it is uncertain.

That is the criticism I make of this first set of statements. Those equations mean nothing to me. I hope they do mean something to somebody who is brighter than I am, but I would like to have him put it in clear-cut language.

These economists are peculiar fellows anyhow. I could name you a noted economist, who became so imbued with his theory that in the glamorous 1920's he took all his money, and all the money of his friends, for investment in the stock market. He had it all figured out. That is the peculiarity of an economist—he thinks he has got the thing right down pat. Well, that poor professor, now past seventy, I guess is living on his pension, and he and his friends are taking in each other's washing to make a living.

Of course, the economists say that we outsiders are butting in on a particular business of which we have no knowledge. So, I, being a layman, proceeded to test

some of these economic conclusions myself. A number of years ago, I began to assemble newspaper clippings of the different talks by economists, I compared their statements, and I also checked the statements that they had made many years before with the outcome of things. Well, the result was humorous.

The supreme test of any science is this: Can its methods lead to correctly predicted results? As a fine illustration, take astronomy. If an astronomer said, "We are going to have an eclipse of the sun tomorrow morning at eleven o'clock" and it occurred a week later, we would say, "Astronomers don't know what they are talking about". You don't have to be a mathemetician or a skillful astronomer to detect that.

Chairman Ridgway: I think I stated that no member of this committee was an economist. I hope there isn't an economist in this Association. These are not mathematical equations; they are, rather, statements. We put the equality sign in there because we did not have anything better. They are really the expression of a principle in its briefest possible form.

You will find in Conclusion No. 1, and these other conclusions that you have adopted, that these things which are indefinite are reduced to their equivalent cost in the designing of the structure to meet the utility requirements. I would like to read just one of the sub-paragraphs in Conclusion 1, "Utility". It says:

"Consideration must be given to the following governing factors: Frequency and speed of trains; character and volume of both passenger and freight traffic; discharge characteristics of stream, or character and volume of traffic over which rail traffic is carried."

Now, that means river traffic, highway traffic, other railroad traffic. If a structure is designed to meet those requirements, its value as to utility will be reflected in the cost of that design. We think there are figures for these things.

(The motion was then put to a vote and carried.)

Vice-President Hastings: The committee is excused with the thanks of the Association. (Applause)

DISCUSSION ON WATERPROOFING OF RAILWAY STRUCTURES

(For Report, see page 361)

(Vice-President Fanning presiding)

Chairman J. A. Lahmer (Missouri Pacific): The committee is confronted with several open questions which are outlined in the report. In addition, several other questions have been brought up by outsiders, most of them producers, in regard to the specifications for membrane waterproofing which were adopted several years ago.

The committee would like to have the views of any members of the Association based on their experience, or knowledge from any other source, in regard to ductility for asphalt for use in membrane waterproofing above ground. The ASTM specifications for this material require a ductility of 15 at a temperature of 77 deg. F. Our specifications adopted in 1934 and also those adopted in 1927, call for a ductility of 20. The ASTM has no requirement for ductility at a low temperature. Our specifications call for a ductility of 4 at 40 deg. F. Your committee thinks that such a ductility requirement is necessary in order to indicate the behavior of the asphalt at a low temperature and also because there is a well supported belief among asphalt technologists that a ductility requirement at 40 deg. F., will exclude some asphalts that are either too highly blown or too brittle.

The ASTM is still considering the subject, and this committee will continue its study with the hope of reaching an agreement.

Vice-President Fanning: Is there any discussion on this report, or on Mr. Lahmer's remarks on ductility? If not, the report will be received as information and the committee will be excused with the thanks of the Association. (Applause)

DISCUSSION ON ECONOMICS OF RAILWAY LABOR

(For Report, see pp. 333–360)

(Vice-President Hastings presiding.)

Chairman F. S. Schwinn (Missouri Pacific Lines): Eight of the eleven assigned subjects are completed and three include recommendations for inclusion in the Manual.

The committee reports progress in study on subject 2, Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work; on Subject 8, The relative economy of combined vs. separate bridge and building gangs, and Subject 9, The effect of modern equipment and machines on bridge gang organizations and efficiency.

Subject 3, Economics of methods of weed killing, has been handled in two parts and the matter presented in Appendix A covers the second part designed to complete the assignment. As a whole, the report has required considerable research and includes valuable information on the control of the more common kinds of vegetation.

Mr. C. W. Baldridge, chairman of the subcommittee, will present the report.

Mr. C. W. Baldridge (Atchison, Topeka & Santa Fe): The subject which has been handled by Subcommittee 3, has been under study by the committee for some years and in 1935 it was decided that it properly should be divided into two parts, the first part to include weeds and vegetation growing in the roadbed and the shoulders thereof, the second part to include weeds and vegetation growing in the right-of-way outside of the roadbed, and in other grounds for which the railway company is responsible. At the convention held in 1936 the committee presented an extensive report covering the eradication of vegetation in the roadbed. The committee's report, which is given in the Proceedings, Volume 37, page 236, presents valuable information about weeds.

The second part of the subject was passed along and it finally fell to the members of this subcommittee to wrestle with big weeds that grow on the right-of-way. The members of the present committee were able to prepare the report which is now submitted for your consideration. Owing to the fact that the information developed on this subject is divided between the report in Volume 37 and the report of this committee this year, the matter of conclusions was handled by the committee as a whole, and the results reached will be presented in the report of the Subcommittee on Revision of Manual.

Vice-President Hastings: Is there any discussion on this part of the report? If not, it will be received as information.

Chairman Schwinn: Subject 4, Organization of forces and methods of performing maintenance of way work, has been studied by this committee since 1931, and the reports presented have included organizations and methods for rail laying, tie renewals, ballasting and servicing operations, both gas and arc-welding organizations for reconditioning rail.

Pending new developments, it is considered that the subject, with this year's report on the construction and maintenance of wooden trestles, has been fully covered. Mr. H. E. Kirby, chairman of the subcommittee, will present the latest report, appearing as Appendix B.

Mr. H. E. Kirby (Chesapeake & Ohio): This report is found on page 337.

As the chairman stated, in previous years the studies presented by this subcommittee have dealt with the major operations required in the maintenance of railway track and roadway. These operations, comprising a definite number of steps, by their nature were susceptible of complete analysis. Once the required number of such steps was determined, they were repeated in identical manner during a time interval necessary to produce a given result. It was than possible to evaluate the several steps, and arrange for each man the work he was to perform in routine manner, repeating the same operations daily. It may be said, then, that these major jobs were of a type to lend themselves more or less readily to definite organization of the working forces.

The present assignment, covering forces working on wood trestles, cannot be given precisely the same treatment as has heretofore been possible. The nature of the work is different, as it is not a constant repetition of identical operations. Rather the process is a mixture of several operations, some of which are similar, but in which the similar steps do not follow one another with the same regularity. Hence, the problem lies more in the determination of the economical size and consist of a gang to carry out a definite program than in a detailed analysis of gang organization and application.

The current report represents studies based on responses to the questionnaire addressed to 48 selected railroads which were believed to represent a cross-section of practices in effect throughout the various sections of the country.

It is believed that with this report, as the chairman has stated, this series of studies may be brought to an end for a time, since all the major operations of track maintenance have been covered, as well as several of lesser importance.

It is recommended that this report be received as information.

Vice-President Hastings: It will be so received.

Chairman Schwinn: Subject 5, The effect of increased weight of rail on track labor, has been given careful consideration by a subcommittee, after reviewing all earlier information on the subject. I will ask Mr. E. T. Howson, subcommittee chairman, to present this report as given in Appendix C, which includes recommended conclusions for inclusion in the Manual.

Mr. E. T. Howson (Railway Age): As the railways have made greater use of heavier rail during the last few years, it is to be expected that numerous studies have been undertaken to determine the economies resulting from this added expenditure. As a result, several reports have already been presented to this Association, the most recent one being in the Proceedings for 1938, page 585. However, the report which your committee now presents is believed to be the first to be brought before the Association dealing specifically and exclusively with the effect of the increased weight of rail on track labor.

In studying the effect of the increased weight of rail on track labor, the committee was faced with the fact that the system of accounting prescribed by the Interstate Commerce Commission does not lend itself to an allocation of costs in such a way that the items of track labor that are affected by increasing the weight of rail can be segregated wholly from those that are affected by other causes, and that this would probably be true of any other practical system of accounting. The effects of heavier rail on track labor are both direct and indirect, and this labor is also affected by numerous factors that are independent of the weight of the rail, while some effects, such as the life of ties, can be determined only after a considerable number of years. For these reasons, the effect on track labor of increasing the weight of rail cannot be stated statistically without making certain assumptions that are not universal in their application.

The committee therefore undertook a study of the attitude and experiences of the railroads that have gone to the use of heavier rail, and its report is based upon returns

recieved from 39 railroads in the United States and Canada, with a total combined mileage of 226,000, or more than 90 percent of the important mileage of the country.

The report shows what we all know to be a fact, that the weight of rail has increased steadily during recent years. The returns from the roads also confirmed what we know to be a fact. In arriving at the decision to increase the weight of rail, no consideration was given by the roads under study to the possible savings in track labor, or, at most, this was a secondary consideration, although every road studied expected that some savings of this character would result. With few exceptions, the primary reason for going to heavier rail was the fact that, with increasing axle loads and higher speeds, the lighter rail was not standing up, so a stiffer track became a necessity, regardless of other considerations. Most of these roads foresaw that with the still heavier wheel loads and the still higher speeds of the future, the amount of labor necessary to keep the track to the desired standard, together with all other costs for track maintenance, would increase unless they adopted heavier rail, so that heavier rail became a matter of avoiding mounting labor costs rather than that of reducing the labor item below the existing level.

Beginning with 1934, a further factor was introduced with the sharp increases that were made in the speeds of both passenger and freight trains, for smooth-riding track and assurance against track defects that might endanger safety at high speed have become paramount on those lines over which high-speed trains are being operated.

In studying the effect of increased weight of rail, numerous, incidental influences come in. Those are reviewed on pages 341, 342 and 343. It is known that heavier rail outlasts lighter rail and reduces the amount of labor required for the replacement of rail over a period of years. It is known that heavier rail and stiffer track reduce the destruction of ties, extend their life and reduce the amount of labor required for their renewal. We know there is less destruction of ballast with the stiffer rail construction. All of those factors affect the amount of labor required to maintain a track to a given standard.

From two railroads we found quite detailed, specific information, which we are presenting on pages 343, 344 and 345, dealing with the reduction in labor actually following installations of heavier rail. One of these is the Kansas City Southern, in which it will be recalled that the early report of an installation of rail to determine the economic weight of rail justified on that railroad, was presented before this Association in a monograph, that formed part of the report of the Committee on Rail in 1930, Mr. A. N. Reece, chief engineer of that railroad, brought the results of that study more nearly up to date for this committee, and these results appear on pages 343 and 344 of the report.

On the Bessemer & Lake Erie the committee found another clear cut record that showed definitely the effect of heavier track. This road began to replace 100-lb. rail with 130-lb. rail in 1917, and by 1921 about 60 percent of the main-track mileage had been laid with the heavier rail. The records of this railroad showed that there was a decided reduction in man-hours beginning with 1922, with a continuing decrease as more of the heavier rail was laid. These reductions are shown in tabular form on page 345 of the report.

The committee presents the following conclusions which it recommends for adoption and publication in the Manual.

(Mr. Howson read Conclusions 1 to 5, inclusive, on page 346.)

Mr. Howson: I move the adoption of these recommendations for inclusion in the Manual.

(The motion was seconded.)

Mr. Geo. S. Fanning (Erie): Mr. Howson, I would like to ask over what period your 40 percent saving applies. You say you are going to have a saving of 40 percent of the cost of rail, or something. Over what period is that?

Mr. Howson: In reply to Mr. Fanning's question, you will note that the committee says that the saving may reach 40 percent. I am not entirely clear as to just what Mr. Fanning has in mind as to the period, because the figure of 40 percent would cover any period after the new rail is put in.

Mr. Fanning: You mean that is a summation?

Mr. Howson: Yes. The committee did not make a definite statement, but stated that the saving may reach 40 percent. Some roads have reported savings as high as 50 percent.

(The motion was put to a vote and carried.)

Chairman Schwinn: Subject No. 6, Economies in labor to be effected through increased capital expenditures, is presented in Appendix D. This constitutes the final report covering the studies of the subject for a period of five years. Mr. G. M. O'Rourke, chairman of the subcommittee, will present the report.

Mr. G. M. O'Rourke (Illinois Central): Appendix D on page 346 reviews briefly the work of the committee in developing the economics in labor to be effected through increased capital expenditures for various items, roadway, track construction, machinery and devices. The current report offers additional information concerning subsoil drainage, treated versus untreated ties, labor-saving machinery, bridges and buildings, signals and interlockers, with the conclusion:

The studies of your committee show conclusively that marked economies can be obtained by certain capital expenditures and should be given consideration whenever funds are available.

It is recommended that this report be received as information.

Vice-President Hastings: If there is no discussion of this matter, it will be so received.

Chairman Schwinn: Subject No. 7, Sanitary provisions in camps and care for housing labor, was extensively analyzed in collaboration with Committee 13. The results of this study are given in Appendix E which also includes material recommended for adoption and publication in the Manual I will ask Mr. J. B. Martin, subcommittee chairman, to present this report.

Mr. J. B. Martin (New York Central): The report of this subcommittee is found on page 350, and was prepared in collaboration with Committee 13–Water Service, Fire Protection and Sanitation from which valuable information and assistance was received.

(Mr. Martin then read the first two paragraphs of the report.)

Mr. Martin: Committee 13 has prepared information on sewage disposal, disinfectants, etc., and the care of drinking water, which has been adopted and published in the Manual. Included in the Manual material of Committee 22 are plans for camp cars that are supplemented by references to sanitary provisions, but it was felt that this material should be supplemented by specific regulations regarding sanitation. Accordingly, the committee submits the following additional sanitary provisions for camps and boarding cars for housing labor, beginning with paragraph (a) Food, which covers the care, handling of food, and preparation of it; disposal of garbage; (b) Dishwashing; (c) Care of floors; (d) Linen; (e) Drinking water and its care, also water for culinary purposes; (f) Toilet facilities, which are already covered in Chapter 13 of the Manual; (g) Shower, wash and toilet car; (h) Control of insects and rodents; (i) Medical inspection; (j) Laundry; (k) Housekeeping; (l) Location of camps and cars; (m) Polic-

ing, and (n) Inspection. We have included in the report a suggested form of blank for reporting the results of inspections. Where such a system has been used, it has been found that there was an immediate and marked improvement in conditions of camp. This blank is included as a matter of information. The committee recommends that subdivisions (a) to (n), both inclusive, be accepted for publication in the Manual; and that paragraphs (7) and (9) on page 22–9 of the Manual be deleted, and I so move, Mr. President.

(The motion was seconded.)

Vice-President Hastings: Is there any discussion.

Mr. W. A. Radspinner (Chesapeake & Ohio): While I realize that the provisions are sanitary provisions, yet the portion offered for inclusion in the Manual provides for the inspection of housekeeping and matters of that kind which are closely allied with fire protection. It is my thought, that there should be included in the requirements, first-aid fire protection of camp cars. You cannot use the ordinary soda ash extinguisher but you can use the pump type which does not splash and which can be prepared to prevent freezing. If you have electrical gangs, you have equipment which should be protected by the carbon tetrachloride or carbon dioxide extinguishers. It seems to me that some provision should be made for fire protection.

Mr. Martin: It was felt that the assignment given to this subcommittee did not cover that feature. That would be within the province of some other committee. I realize that fire protection is very important and should be covered, but it would seem that it should be handled by Committee 13.

Mr. Radspinner: The reference you give to Committee 13 was prepared before fire protection was assigned to that committee.

Mr. Martin: We have given those references to show where information on these sanitary provisions will be found in the Manual or the Proceedings.

Vice-President Hastings: Is it not true that the matter of fire protection is not one that is directly related to the economics of railway labor but the matter of sanitation is?

Mr. Martin: Yes, that is true.

Mr. Radspinner: I don't know about that. You have quite a little money invested in some of those camps. I think that is economics just as much as sanitation. If you lose the camp cars you lose as much value as if you have one of the men sick.

Mr. Martin: It seems to me that it is up to someone to decide to whom that assignment belongs.

Vice-President Hastings: We might leave that with the Outline of Work Committee of the Board of Direction.

Mr. E. R. Lewis (Michigan Central): Under (n) Inspection, page 355, next to the last line, "with a view of bringing about a constant improvement of conditions," I wonder if that is just what the committee means, whether it isn't rather the maintaining of high standards. It might not always be possible to keep on improving conditions. I suggest substituting the words "maintaining high standards."

Mr. Martin: In its investigation, this committee found that some camps were located at outlying points, and that practically no one paid any attention to them except the men who lived in them. Sometimes they got into bad condition. It was felt that some system of inspection would eliminate such a condition as that.

Mr. Lewis: You might not be able to improve it.

Mr. Martin: It will reach a point of improvement finally or should.

Mr. Lewis: Is this Manual language or isn't it?

Mr. Martin: This is Manual language.

(The motion was then put to a vote and carried.)

Chairman Schwinn: Subject 10, The economic relation between supervision and labor, has been studied by a subcommittee under the direction of Mr. L. L. Adams, who will present this report.

Mr. L. L. Adams (Louisville & Nashville): The report of this subcommittee will be found on page 355, Appendix F. This is a very elusive subject, and we were unable to reach an exact answer for reasons given in our report. However, we feel that the information as given in the addenda should be of value to any one desiring to make a study of this subject as related to his road, as this information gives a sound basis for the conclusions reached by your committee, namely:

(1) The ratio of supervision to labor is an individual problem to each railroad.

(2) The ratios in 1929 and 1937 were not the most economical in every respect.

(3) General economic conditions will always affect the ratio of supervision and labor.

It is recommended that this report be received as information.

Vice President Hastings: It will be so received.

Chairman Schwinn: Subject 11, The effect of sudden fluctuations in maintenance expenditure allowances on maintenance costs, is one which has given all of us much concern. A review of the subject is given in Appendix G, which also includes a conclusion recommended for publication in the Manual. Mr. Armstrong Chinn, chairman of this subcommittee, will present the report.

Mr. Armstrong Chinn (Alton): The committee was unable to find any road that kept its cost figures in such shape that a definite dollar-and-cent answer could be developed but, from the information collected, certain facts stand out, which are shown in the report, together with a conclusion that is recommended for adoption and publication in the Manual.

It is therefore recommended that the report be received as information, that the conclusion be adopted for publication in the Manual and that the subject be discontinued. I move the adoption of the conclusion which reads:

"Sudden fluctuations in maintenance expenditure allowances increase labor costs and adversely affect the quality of the work."

(The motion was seconded, put to a vote and carried.)

Chairman Schwinn: Subject 1, Revision of Manual, is covered by Appendix H, page 357. The material in this report, included under paragraphs (a) to (g), refers to the revisions and additions to the Manual as recommended under Appendices C, E and G. These have been independently adopted as presented by the subcommittee chairmen. Under paragraph (H), page 360, we propose certain matter for publication in the Manual, which is designed to record basic principles which relate to weed control as developed by the committee's studies during the past three years.

(Mr. Schwinn then read the five paragraphs under the heading "Weed Control" on page 360.)

Mr. Schwinn: Those paragraphs are the Manual material which your committee has developed in connection with the subject of control of weeds, and I move their adoption.

(The motion was regularly seconded.)

Vice-President Hastings: Is there any discussion?

Mr. H. E. Tyrrell (Southern): Those statements are statements of fact, undoubtedly, in connection with the handling of weeds, but I don't see that those statements constitute Manual material. There is no cost involved, no analysis one way or the other. It doesn't seem to me that that is Manual material at all.

Chairman Schwinn: The material which your committee has proposed here for inclusion in the Manual has been developed with a view of setting out such facts as have been brought to the attention of this committee, which indicate the value of expending money for weed control. When presented in the Manual, and they have become a permanent record, they are things to which we as maintenance men can refer and can base our requests for assistance in that part of our work.

Vice-President Hastings: Is there any further discussion?

(The motion was put to a vote and carried.)

Chairman Schwinn: That concludes the report of Committee 22.

Vice-President Hastings: This committee has presented a splendid report. It is to be congratulated upon the fine work that it has done, and they are now excused with the thanks of the Association. (Applause).

DISCUSSION ON MAINTENANCE OF WAY WORK EQUIPMENT

(For Report, see pp. 305-331)

(Vice-President Fanning presiding.)

Chairman G. R. Westcott (Missouri Pacific): In his address this morning, President Morrow said in effect, that it was desirable that committee reports be made promptly, that is, as information developed it should be brought to the attention of the Association, but he added that this should not be done at the expense of completeness and reliability. I do not present this thought as an apology, but in explanation of the fact that out of 14 assignments this year, we are only reporting progress in study on 8 of them, as follows: (1) Revision of Manual; (2) Standardization of parts and accessories for railway maintenance motor cars; (4) Self-contained direct-blow gasoline tampers; (5) Concrete vibrators; (8) Sand blasting equipment; (9) (a) Track welding equipment; oxy-acetylene; (b) electric arc; (13) Safety devices for work equipment.

It was the expectation up to within a few days of the time we were required to have our report in the hands of the secretary, that three other subjects would be completed this year, but we decided that they should be held over for further investigation. We are presenting reports on the remainder of the assignments. This first one, No. 3, Depreciation of work equipment, will be presented by Mr. C. H. R. Howe.

Mr. C. H. R. Howe (Chesapeake & Ohio): In last year's Proceedings this subcommittee presented a report showing at length a tentative list of rates of depreciation on various pieces of roadway equipment. The tabulation was complete in so far as our knowledge went. The subject was carried over until this year in order that this committee might collaborate with the Committee on Records and Accounts in order to elaborate further, if necessary.

After that collaboration it was concluded that there were not enough factual data in existence to allow us to present a final report. Until such time as more data are available, it is recommended that the subject be discontinued.

Vice-President Fanning: The Outline of Work Committee will take note of that recommendation.

Chairman Westcott: Subject No. 6 is Methods of keeping data on work equipment. For reasons that appeared good to the committee, and I trust the convention and the Board of Direction will forgive us, we have taken a rather liberal view of this assignment and have injected into it some matters of record-keeping that do not relate to cost data. Mr. Hutchison will present the report.

Mr. N. W. Hutchison (Chesapeake & Ohio): The report of Subcommittee 6, Methods of keeping data on work equipment, is found on pages 306 to 312, inclusive. Obtaining and recording data relative to work equipment are generally accepted as a desirable practice, the nature and extent of which are dependent upon the needs and wishes of the responsible officers of the individual railroads. The report this year is confined to motor cars and, for the benefit of those interested, several forms have been designed and are illustrated as part of the report on pages 307 to 312, inclusive, as follows:

(Mr. Hutchison then read the descriptions of Forms 1 to 6, inclusive, as given at the bottoms of pages 306, 307, 308 and 310, and submitted the report as information.)

Vice-President Fanning: Is there any discussion on this report? If not, it will be received as information.

Chairman Westcott: On most railroads, as I think nearly everyone here will agree, the use of work equipment, like Topsy in Uncle Tom's Cabin, just "growed". The machines were installed without any particular plan. There was no means of saying just where or when they could best be used. In recent years we are beginning to realize that the use of machines is something big enough to be given careful thought. Subject No. 7, Scheduling the use of work equipment, will be presented by Mr. C. E. Morgan.

Mr. C. E. Morgan (Chicago, Milwaukee, St. Paul & Pacific): This report is found on page 313. Scheduling the use of work equipment in order to secure more working days' output from those machines is necessary if full use is to be made of the money invested in that equipment. More people are becoming conscious of the extreme importance of securing both the best possible quality of output as well as the lowest unit cost for such work. The report lists about twenty types of work on which scheduling can be handled effectively. A survey was made of the railroads represented in Committee 27 to learn, not from the chief engineers or from the maintenance of way engineers, but from the men who were directly associated with work equipment, what was the best possible way to handle assignments of equipment.

The table on pages 313 and 314 summarizes the opinions which that survey brought out. It will be noted that there is quite a diversity of opinion as to how the machines should be assigned. This can be explained by the different conditions affecting the work to be done. Among these are organization, both of gangs and supervisory forces; climatic conditions; and the extent to which the road is mechanized. The procedure and the results that may be expected, as set forth in the detailed discussion which follows, are based on the practice of one large railroad, quite fully mechanized, on which the distribution of men, materials and machines is under the control of one department head. Under less favorable conditions, as for example, where there is a shortage of machines, the results obtained may be less satisfying, but in this case the need for scheduling the work and the machines, in order to secure full utilization of the equipment available, is more obvious.

(Mr. Morgan then read the seven paragraph headings on pages 314 and 315.)

Mr. Morgan: I mention these seven, because each of the seven constitutes a large problem in itself, and the details of that are usually dependent upon the conditions on your own railroad. (He then read the conclusions on page 315, and offered the report as information.)

Vice-President Fanning: Any discussion? It is an excellent presentation, Mr. Morgan.

Chairman Westcott: In the absence of Mr. Zavatkay, chairman of the subcommittee, I will present subject No. 10, Railway owned automotive equipment and, in the judgment of Committee 27 it is a very timely subject. The railroads have perhaps been a

bit slow in availing themselves of the advantages that can be found in the use of automotive equipment in carrying out their work. The report is on pages 316 to 326 and is based largely on the experience of one railroad which, perhaps, more than any other in the country, has made use of automotive equipment and has found it exceedingly economical as a means of doing maintenance work. Probably I should not limit that altogether to maintenance; let's say, doing work. It reaches out into some lines other than those relating strictly to maintenance. The report contains a catalog of the automotive equipment used, and some very interesting data on the operation of the equipment. It is supplemented by certain forms that are used in the operation and maintenance of the equipment, by views showing the character of the equipment used, and a specimen of specifications for one of the items. The conclusions drawn from the report are found on page 324.

(Chairman Westcott read the conclusions.)

Vice-President Fanning: Is there any discussion on this report?

Mr. C. E. Smith (New York, New Haven & Hartford): Coming from New England, I can possibly apologize for Mr. Zavatkay's absence by telling you we had a snowstorm, from 8 to 12 in. deep Sunday, and a lot of it turned into sleet. I think Mr. Zavatkay is at home quite busy with his work equipment digging the railroad out.

The report presented by Mr. Westcott is quite complete, but I might add that the New Haven has possibly gone farther than any railroad in this country in the use of automotive equipment on the highway. We buy automobiles for our traffic solicitors and for our police, as well as for our operating and maintenance forces. We have about 100 trucks in the maintenance of way department and the mechanical department. They have very largely taken the place of work trains. Our paint gangs, our building gangs, our section gangs, all but the very largest extra gangs, go out and reach their points of contact with the railroad by truck, trucks that handle tools, material, and have benches in them for men. The Mechanical department also uses highway trucks in connection with the repair of equipment set out at outlying points. There is also another field where the railroads are going to employ automotive equipment on the highway and that is in this rapidly growing door-to-door service, the pick-up and delivery of less than carload freight.

Right now the New Haven railroad is performing about half this service with the trucks of its subsidiary, the New England Transportation Company, and about half with the trucks of contract truckers at various points on the railroad. But I believe as time goes on, if the railroads do as they have done in all their other activities in the past, they will lean more and more toward buying their own equipment and running their own equipment for performing their own services.

So I believe the maintenance people (and I believe it will fall into the hands of the maintenance of way department) are going to have a large and growing job in the maintenance of automotive equipment as time goes on.

Mr. R. H. Ford (Chicago, Rock Island & Pacific): It is no reflection on the other reports, the many very excellent ones that have been before the convention, to say that this report is one of the best that I have ever read. I speak of it particularly not for the benefit of the committee but rather because it touches one of the very vital points in railroading today. Conditions have so changed that this matter of mechanized equipment has become, to my mind, one of the very vital things that this Association must develop. The reports shows a wide diversity of views, and the committee is to be commended for the way it has presented the information.

There is, however, one thought that I hope the committee will find ways to develop this coming year, and you will find as you read the report that it was not

overlooked. I refer to crawler or off-track machines and I am hopeful that the committee will follow up its good work on this particular type of equipment. There are various reasons why this should be done, which I think ought to suggest themselves to the members of this Association. I know that this committee has in mind the altered conditions with respect to labor, train operation and speed, about which Mr. King spoke so aptly. There is another field in which those altered conditions apply, and that is the great change that will have to come in the matter of ditching and drainage. I know of one railroad that is using machines of the crawler type to alter the slopes of cuts for the purpose of obviating repeated ditching operations. I do not want to take the time of the convention except to say that I have had inquiries from four large truck manufacturers regarding the research work they would like to undertake on this question of the crawler type of machine. The crawler is all right, but what is it the railroads need? What is the railroads' problem with respect to this?

My remarks are made for no other reason than to ask that you men who are within my hearing, who have to do with maintenance and construction, to aid the committee in this study, and perhaps the Board of Direction will make a definite assignment that will direct attention specifically to this problem.

Vice-President Fanning: Is there any further discussion?

Chairman Westcott: For several years we had quite a lengthy discussion of crawler-type or so-called track-type tractors and, in a way, wore out the subject, getting to a point where we didn't see just exactly what the next move in our studies should be. We expect that this year we will have on our docket for study two subjects that are right in line, I think, with what Mr. Ford is talking about. One of them is pneumatic-tired tractor equipment, which is coming into more general use in industry, though it is rarely used on the railroads. Another item is off-track ditchers. I think this is just what Mr. Ford has in mind. To revert for one moment to the matter of the crawler tractor; it is just a bit hard to handle because the work that can be done by the tractor is so varied. So much auxiliary equipment is required that it becomes almost necessary to select for each particular item of work, just exactly the machine equipment best fitted for it.

Vice-President Fanning: Any further discussion?

Mr. Ford: I think it is pretty generally agreed that the type of machine we need is not now on the market. I am pretty well satisfied in my own mind, from conversations I have had on the subject, that our problem is very much the same as that of the Rail committee in the development of rail. You men, aided by the information that you ought to get from many of the men in the Association will, if I am correct, be able to lend valuable assistance in the development of the type of machine we need. Ultimately I expect to see at least 80 percent of our ditching done away with on most of our main lines. I believe the time is not far distant when we will find the way to maintain a uniform slope, but to do that we need a totally different type of machine from any on the market today. In stating that, I am only quoting manufacturers who are looking into the subject.

Vice-President Fanning: If there is no further discussion, the report will be received as information.

Chairman Westcott: The next subject covers an item of equipment that is not very well known on western railroads, and yet it is probably one that, because of the current use of heavy rail, is worthy of some investigation. Mr. Earl Mills will present the report on Rail Saws.

Mr. E. H. Mills (New York Central): The report submitted by this subcommittee is found on pages 326 to 329 and contains all the pertinent information on the subject of rail saws that we were able to assemble up to the time of publication.

I wish to mention at this time only a few of the outstanding points brought out. We find the principal use is to eliminate very slow hand methods and provide greater safety where a considerable number of accurate cuts must be made in the field.

All saws available are relatively slow compared with rolling-mill cutting devices or burning by the oxy-acetylene torch. If the saw manufacturers can develop portable saws with greatly increased cutting speeds, their use will undoubtedly find wider application.

The conclusions reached by this subcommittee were as follows:

(Mr. Mills then read the conclusion on page 329, and offered the report as information.)

Vice-President Fanning: It will be so received.

Chairman Westcott: The use of power tools in track and other roadway work has perhaps outstripped the use of power tools in bridge maintenance. Subject 12, which I will present, covers this matter, and is found in Appendix F, pages 329 to 331.

The basis for this report was the replies to a questionnaire sent to a number of railroads to determine just what tools were being used. These replies indicated that, while some roads are well equipped, having a considerable number and variety of power tools, others have comparatively few, and still others are just now studying the problem. The report mentions particularly only three or four specific items that are perhaps worth more consideration than others. One of them is the so-called impact wrench, which has the decided advantage of high speed when the nut turns easily combined with great power when the nut has been brought home.

Another item is the chain saw which can be used for cut-off work on heavy timber, piling, and so forth. It may be operated either by air, electricity or gasoline. Still another is the flexible shaft for the operation of tools for various purposes.

The conclusion is very short, but, I think, to the point. "The consensus of reports indicates that further mechanization of all bridge and building work offers worth while opportunities for increased economies". The report is submitted as information.

Vice-President Fanning: Is there any discussion on this report? This committee has made an excellent presentation of valuable and interesting reports and is excused with the thanks of the Association, Mr. Westcott. (Applause.)

DISCUSSION ON TRACK

(For Report, see pp. 543–592)

(Vice-President Hastings presiding)

Chairman C. J. Geyer (Chesapeake & Ohio): If there is no objection we will withhold Subject 1, Revision of Manual, until action has been taken on the other parts of the report. Subject 2, Fastenings for continuous welding of rail, appears on page 549. I will ask Mr. Magee, chairman of the subcommittee, to submit the report.

Mr. G. M. Magee (Association of American Railroads): This year, the subcommittee inspected a one-half mile installation of continuous welded rail on the Central of Georgia Railway. This installation is of particular interest because no special type of rail fastening was used, the rails being held in place by double-shouldered tie plates, cut spikes, and six rail anchors per rail length for a distance of 275 ft. at each end of the welded rail.

Through the courtesy of the engineering staff of the Central of Georgia, measurements of the end movements and of the temperature stresses were obtained at various

temperatures throughout the year. Measured end movements are shown graphically on pages 552 and 553, and the measured temperature stresses on page 555. The principal differences between the performance of this track and installations with the welded rail secured to each consecutive tie are as follows:

1. The end movements for a given temperature change are about twice as great on this installation.

2. The anchorage provided at each end was not quite sufficient to restrain the welded rail completely at its center against temperature movements.

On page 558 is a report by Mr. P. O. Ferris on the performance of the Delaware & Hudson welded installations to date, and on page 560 a report by F. R. Layng on the experience with the Bessemer & Lake Erie welded installation. Based on observations of continuous welded rail with various types of fastenings, the subcommittee gives on page 562, four comments on the longitudinal, lateral and vertical holding power required of fastenings and on the laying temperatures for welded rail. These should not be considered in any sense as conclusions, but rather as a summary of observations to the present time.

The subcommittee also has an assignment to design a screw spike to be used as a separate plate fastening. A progress report on this assignment is included.

The committee submits this report as information.

Vice-President Hastings: Is there any discussion? It will be received as information.

Chairman Geyer: Appendix C, Plans and specifications for track tools, begins on page 563. I call attention to the fact that the personnel of the subcommittee should include Mr. J. H. Kelly. I will ask Mr. Roller, chairman of the subcommittee, to present this report.

(Mr. W. L. Roller, Chesapeake & Ohio, read the text of Appendix C, covering Plan 8A for Timber Tongs, and recommended that it be received as information.)

Vice-President Hastings: Is there any discussion of this part of the report? It will be received as information only, the idea being that at a future time this new Plan 8A will be offered for adoption.

Chairman Geyer: This committee will be very glad if the members will examine the tool plans submitted as information, from time to time, and forward any comments, criticisms, or suggestions for changes, and the reasons for them, so that we may use such information in placing these plans in final form for printing in the Manual as recommended practice.

Appendix D, Plans for switches, frogs, crossings, slip switches, etc. Mr. Caruthers, chairman of the subcommittee, will present the report.

Mr. E. W. Caruthers (Pennsylvania): The report of the subcommittee is found on page 564 and reads as follows.

(Mr. Caruthers read Appendix D.)

Mr. Caruthers: The committee recommends that Plan No. 121, 11-ft. Curved Split Switch with Uniform Risers, and Plan No. 405, No. 10 Spring Rail Frog for Heavy and Medium Weight Rails—Short Spring Rail Type, be adopted as recommended practice and published in the Manual, and I so move.

(The motion was duly seconded, put to a vote and carried.)

Chairman Geyer: Appendix E, Corrosion of rails and fastenings in tunnels. Mr. Perlman is chairman of this subcommittee. The report is merely one of progress, with some review of previous information presented.

Vice-President Hastings: It will be so received, Mr. Chairman.

Chairman Geyer: Appendix F, Practicability of using reflex units for switch lamps and targets. Mr. Sitton, chairman of the subcommittee, will present the report.

Mr. G. L. Sitton (Southern): The report of Subcommittee 7 will be found on pages 566 and 567. The purpose of this report is to present information somewhat more up to date than was included in the 1933 report. The committee found that there has been considerable interest in this subject since that time, and quite a number of units have been installed. However, the information obtained does not warrant a recommendation for adoption and publication in the Manual, as there is still a considerable difference of opinion on this subject. Interest seems to vary from practically zero to a considerable degree of enthusiasm.

It is believed that this report will be of value because of the information presented on the savings which can be made by the use of reflex units. This is shown about the middle of page 567. The committee believes that any railroad which has not given this matter serious consideration will be justified in doing so on the basis of the savings which are possible. It is realized, of course, that reflex units are not practical at all locations.

We have undertaken to show in the report the general opinions of the roads which have used them. In all cases we have given the views of the majority, a considerable majority generally.

This report is offered as information.

Vice-President Hastings: Is there any discussion on this part of the report? It is offered as information, and it will be so received.

Chairman Geyer: Appendix G, Welding of manganese castings in special trackwork, beginning on page 568. This is offered as a progress report, with some information the committee has been able to develop during the year.

Vice-President Hastings: It will be so received.

Chairman Geyer: Appendix H, Bolt tension necessary for proper supporting of rail joints. I will ask Mr. Breed, chairman of the subcommittee, to present the report.

Mr. C. W. Breed (Chicago, Burlington & Quincy): The report on pages 568 and 569 outlines the general program of tests. Following this is a description of the necessary preparation work together with the initial reports of tests on the Milwaukee, the Burlington, and the D. & R. G. W. railroads.

The work of the subcommittee has not progressed to such an extent that conclusions or recommendations can be made. We hope to install other tests on eastern roads during the spring of 1939. Considerable effort has been made to develop means for setting up a predetermined tension of bolts, with encouraging success.

The report is offered as information, with the recommendation that the subject be continued.

Vice-President Hastings: Is there any discussion? The report will be received as information.

Chairman Geyer: The work on bolt tension is reaching a stage where we may expect some real information. We wish that members of the Association interested in this particular subject would watch the development and let the committee have the benefit of anything they have to offer.

Appendix I, Lubrication of rail on curves. This report begins on page 575, and carries a recommendation that the conclusions be adopted for publication in the Manual. At a meeting of the Track committee yesterday, we carefully reviewed the subject matter in this report and we felt it was not quite ready to present for publication in the Manual.

The graphs on pages 578 and 579 did not turn out in printing as we expected them to appear. You will see a note with the words, "One division represents", etc., but these divisions did not appear in the engraving. Because of that and some other things with which the committee is not satisfied, we are going to ask that this report be received as information and the subject be continued.

Vice-President Hastings: It will be so received.

Chairman Geyer: Appendix J, Design of cut track spikes for use with AREA toeless joint bars. I want to make a correction in the personnel of that subcommittee. Mr. H. R. Clarke is chairman of the subcommittee instead of Mr. E. W. Caruthers, as shown. I will ask Mr. Clarke to present this report, inasmuch as it is Manual material.

Mr. H. R. Clarke (Chicago, Burlington & Quincy): The report is found on page 581. Attention was called to the desirability of some such change by the difficulties that were encountered in attempting to use the standard spike with any toeless joint bar. The committee reported on this last year, offering a suggested design and submitted the report as information, with the thought of recommending later that it be adopted and included in the Manual.

Upon further study of the subject and receipt of many recommendations to the effect that, instead of offering the spike for use with toeless joint bars only, it can be offered for general use and as an alternate for the standard spike, the committee acted upon that suggestion, and is now submitting the proposed design of spike as an alternate standard and for inclusion in the Manual. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Geyer: Appendix K, Prevention of brine drippings on track structures, collaborating with Mechanical division. Colonel Arn, chairman of the subcommittee, will present the report.

Mr. W. G. Arn (Illinois Central): Some years ago this committee prepared a report on a somewhat similar assignment, but following its presentation the subject was dropped.

(Mr. Arn then read various portions of Appendix K, pages 583 to 592, inclusive, and offered the report as information, with the recommendation that the subject be continued.)

Vice-President Hastings: Is there any discussion? The report will be received as information.

Chairman Geyer: The subcommittee on brine drippings collaborated with the Mechanical division and has done quite a little work. Unfortunately, the results of the work done have been more or less negative. We had to run down all the ideas that have been suggested, in order to find out if there was anything in them.

Appendix A, Revision of Manual, has been handled by a special subcommittee. There are two or three items to be changed this year. I will ask Colonel Arn to submit the report.

Mr. Arn: The subcommittee submits revisions of the following plans which were adopted in March, 1936:

Plan No. 1—Clay Pick. This is merely revised to show the contour of the back, to get better manufacturing results. The same applies to Plan No. 2—Tamping Pick. I move their adoption.

(The motion was seconded, put to a vote and carried.)

Mr. Arn: Plan No. 4—Track Wrenches for ASA Heavy Nuts. The note was revised to show width of nut instead of size of bolt. There was some criticism that the other type did not show the information to the best effect. I move its adoption.

(The motion was seconded, put to a vote and carried.)

Mr. Arn: The same comment applies to Plan 4A—Track Wrenches for ASA Regular Nuts. I move its adoption.

(The motion was seconded, put to a vote and carried.)

Mr. Arn: Plan No. 11—Claw Bar Design No. 1, has been revised to show additional dimensions, the correct weight and revised tolerance, to provide a better plan for manufacturing. I move its adoption.

(The motion was seconded, put to a vote and carried.)

Mr. Arn: Plan No. 11A—Claw Bar Design No. 2, has been revised as to tolerance. I move its adoption.

(The motion was seconded, put to a vote and carried.)

Mr. Arn: Plan No. 16—Track Chisel Design No. 1 and Plan No. 17—Track Chisel Design No. 2. It was found that the radius of the cutting edge as originally designed did not give the best results and after laboratory and service tests, it was found that this should be changed to make the radius of the cutting edge 1 in. instead of ¾ in. I move the adoption of Plan No. 16 and Plan No. 17 as revised.

(The motion was seconded, put to a vote and carried.)

Mr. Arn: Plans Nos. 774 and 775, Crossings with Solid Manganese Steel Frogs and Interior Rolled Closure Rails.

Some time ago it was suggested that these plans ought to be made more definite by fixing the lengths of the frogs, and it was brought out in the discussions that the design shown on Plan No. 774, for angles below 25 deg. and above 14 deg. 15 min., had not proved altogether satisfactory. Upon going into the matter in detail it was developed that it is extremely uneconomical to make these solid manganese steel frogs long enough to accommodate the long six-hole joint bars now used by some roads, and it was decided to offer designs based on the use of 24-in. joint bars, all of which would be furnished complete with bolts by the maker of the crossing.

From the various study plans which were made and discussed, a number of improvements were suggested, all of which, together with definite frog lengths, have been incorporated in the following revised plans which are offered for recommended practice:

Plan No. 774—Crossing with Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles Below 25 deg. and Above 14 deg. 15 min., Single-Rail Construction.

Plan No. 775—Crossing with Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles Below 14 deg. 15 min. to 8 deg. 10 min., Inclusive, Single-Rail Construction.

I move the adoption of these plans for inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Geyer: Mr. Chairman, that is the report of the Track Committee for this year.

Vice-President Hastings: This committee has, as it has always done heretofore, brought in a splendid report. The work of this committee has been guided for several years by its present chairman, Mr. Geyer. I do not feel that I can dismiss the committee from the platform without offering a word of thanks from the Association for the splendid work which he has done as chairman of this committee. He retires as its chairman this year, and the burden will fall on the shoulders of Colonel Arn.

The committee is excused with the thanks of the Association. (Applause)

DISCUSSION ON MASONRY

(For Report, see pp. 401–433)

(Vice-President Hastings presiding.)

Chairman J. F. Leonard (Pennsylvania): The various appendices will be presented in the order that they appear in the summary of the first page of the report. I will ask Mr. Boyd, who is chairman of the subcommittee on Revision of Manual to present his report.

Mr. G. E. Boyd (Railway Age): The report on Revision of Manual, on page 402, is in two parts, the first referring to specifications for High-Early-Strength Cement. The committee recommends the deletion of Section 2, Fineness, which appears in the speci-

fication on page 8–5 of the Manual, and of paragraph (c), Section 9, page 8–6 of the Manual, relating to the rejection of cement for failure to meet the fineness requirement. As a consequence, if this recommendation is approved, Section 3 and subsequent sections of the present specification will need to be renumbered, and paragraphs (d) and (e) of Section 9 will be redesignated as (c) and (d), respectively.

The committee also recommends that the ASTM designation be changed to C74–37 to conform to the latest issue of the ASTM specification which this follows, and that the asterisk be deleted from the head; it also recommends the deletion of Footnote 1 on page 8–7 and the renumbering of the subsequent footnotes and their references. This completes the committee's recommendation with reference to the High-Early-Strength Cement specification. I move that these revisions of the Manual be approved.

(The motion was seconded, put to a vote and carried.)

Mr. Boyd: The committee recommends the deletion of Sections 1, 3 and 13 of the Specifications for Portland Cement and the addition of a paragraph and footnote to Section 2, the redesignation of this section as Section 1, and the renumbering of all subsequent sections. It also recommends that Sections 8 to 11, inclusive, in the Standard Methods of Sampling and Testing Portland Cement, pages 8–12, 8–13 and 8–14 of the Manual, be withdrawn and that new requirements for the procedures for chemical analysis be substituted. The matter to be deleted is shown in italics, beginning on page 404, followed immediately by the proposed form. The headings of those are Loss on Ignition, Insoluble Residue, Sulfuric Anhydride, and Magnesia. The additional matter which is recommended begins on page 408, and the headings are Ferric Oxide and Alumina, Ferric Oxide, Calcium Oxide, Magnesia and Blank Determination. In addition, certain sections numbered 18 to 21, inclusive, are to be added. This refers to a rapid method for the determination of magnesia and is something new that has been developed since these specifications were first issued. The ASTM designation should be changed to C9–38* and Footnote 1 on page 8–10 should be withdrawn. I move the deletions and substitutions and the additional matter be approved for inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Boyd: That concludes the recommendations for changes in the Manual.

Chairman Leonard: The next assignment, Specifications and principles of design of plain and reinforced concrete, will be presented by Mr. A. N. Laird, vice-chairman of Committee 8 and chairman of this subcommittee.

Mr. A. N. Laird (Grand Trunk Western): The report of the subcommittee appears on page 414. The subcommittee makes no report this year on Composite columns and pipe columns, as it is awaiting further action by the Joint Committee on Concrete on this subject. It also makes no report at this time on Concrete bridge deck slabs of the non-ballast type, nor on Rigid-Frame structures for multiple spans.

It submits the report on Isteg reinforcing steel as information, and asks that this subject be discontinued. That concludes the report unless there is some discussion.

Vice-President Hastings: Is there any discussion of this portion of the report? If there is no discussion, it is received as information.

Chairman Leonard: The next subject, Progress in the science and art of concrete manufacture, will be presented by Mr. L. W. Walter, chairman of this subcommittee.

Mr. L. W. Walter (Erie): This report begins on page 414 and consists of two sections.

Section 1 covers Pressedwood, plywood and special fibrous materials for forms and form lining. During the last several years, recognition has been given to the adaptability of pressedwood and plywood for this purpose. These materials are commercially available in sheets of standard size and thicknesses adaptable to use as form material applied directly to studding or as form lining backed up with sheathing.

This report deals with the manufacture of these materials, their protection, and with some details connected with their proper use and repeated use, together with economic considerations involved. I recommend that Section 1 of the report be received as information, and that the subject be continued.

Vice-President Hastings: Is there any discussion of this Section I? It will be received as information.

Mr. Walter: The second assignment is Standard Portland cement compared with standard high-early strength Portland cement. We have attempted to deal with the requirements and characteristics of the two types of cement in relation to the specification requirements that distinguish one from the other, and with some of the characteristics which may be of interest in the problem of choosing between the two types of cement for any particular use.

One difference between the specification requirements of the two types of cement is the essential difference in strength requirements. The ASTM standard for normal Portland cement strength requirement is based on strength results at the 7 and 28-day test periods; the high-early-strength Portland cement at the 24-hour and 3-day periods, with the further provision that the 28-day strength must be not less than the strength shown at three days. The only difference is a necessary but not particularly significant one.

The most effective means of increasing the strength of cement, and, particularly, of high-early-strength cement, is by finer grinding, but there is nothing in the specification relating to fineness of grinding. The old 200-mesh sieve is now outmoded because of the increased fineness to which both the normal Portland cement and the high-early-strength cement are now ground.

Fineness is now spoken of in terms of specific surface area expressed in square centimeters per gram. While no restriction, limitation or requirement has been set up in the specifications for either, it is the quite general practice to resort to finer grinding in order to produce the strength characteristic of high-early-strength Portland cement. Expressed in terms of square centimeters per gram, the fineness for normal Portland cement lies usually between 1,600 and 1,800 and for the high-early-strength cement usually between 2,000 and 2,400.

By reason of the finer grinding of high-early-strength cement, it is more difficult to control the set and, therefore, provision is made for using somewhat more calcium sulphate, commonly known as gypsum, as a set regulator. That usually carried with it a higher SO_3 content. Accordingly, the maximum allowable in Portland cement is 2 percent and in high-early-strength Portland cement it is 2½ percent. That is a necessary difference but carries with it no particular significance.

The matters of general concern in determining which of the two types of cement is best adapted for particular purposes are strength and durability. In addition to that, however, the question of heat of hydration might well be considered at times.

(At this point Mr. Walter read the first paragraph under Heat of Hydration, and the two paragraphs under Durability on page 417.)

Mr. Walter: We have attempted to list some things that might be considered in making a choice as between the two types of cement.

(He then read Conclusion 1 and Conclusion 2, (a) to (c), inclusive, and the following paragraph, all on page 418.)

Mr. Walter: This report is presented as information, with the recommendation that the subject be discontinued.

Mr. Geo. S. Fanning (Erie): While I realize that it is not a subject for the convention, I have always felt that an assignment to report on the progress in the science and

art of any subject was pretty much a continuing subject. I don't think the committee believes that there is not going to be any more progress in the science and art of concrete manufacture. I hope they do not think so.

Mr. Walter: In reply to Mr. Fanning's remarks, it was not the desire of the committee as a whole, or of the subcommittee, to recommend that the subcommittee be discontinued, but only these two particular assignments.

Mr. C. C. Westfall (Illinois Central): Do I understand that this third assignment is not to be reported upon, or is that to be kept open and reported upon later?

Vice-President Hastings: The committee recommended the discontinuance of the assignment.

Mr. Westfall: I think it would be too bad if the committee is not to complete its study and tell us something about the present-day Portland cement. If the committee wants to discontinue that, I would like to discuss it. The Portland cement we are getting now is so different from what Mr. Walter referred to as normal Portland cement that I think the committee owes it to the Association to give us the benefit of its studies and, if it has not made studies, to make them.

We individually, are working in the dark right now on our concrete work, and we are not getting any particular help from the Portland cement manufacturers because they have not recognized the fact, to us at least, that they are doing any different from what they did ten years ago. I think the committee knows that they are, and we know from the results we are getting that they are. We have to look to this committee to tell us how to handle this cement today differently from the way we handled it five years or more ago. I would hate to see that part of the subject discontinued.

Mr. B. R. Leffler (New York Central): I want to add to Mr. Westfall's remarks. I want to suggest to the committee that, on this subject of the science and art of concrete manufacture, it consider some of the new state specifications for Portland cement. I have in mind, particularly, the State of New York. I do not believe in following the ASTM blindly. I do not need to expand on that; there are certain reasons for it. I think we want to get all the independent views that we can. I suggest we canvass some of these state requirements. For instance, I understand that one of the states has gone back to what the Lackawanna Railroad used years ago, namely, the autoclave method. I am not saying that that is the right thing to do, but let us get some developments from the state engineers.

Mr. Walter: The committee, in the report submitted today, tried to keep within the scope of the subject assigned and that was a comparison of the two types of cement, rather than any study of broader scope. The committee will have under study during the coming year the present status and merits of the autoclave test and will probably be prepared to report on it at the next annual convention.

Mr. Westfall: Subject c, "Needed adjustments in field practice to use present-day cements to best advantage", does not limit the discussion to high-early-strength and normal Portland cement, but I understood from the discussion, when I spoke first, that the subject was to be discontinued. I think that is a subject that has already been assigned to the committee, on which I would like to see a report.

As I understand it, there is only one cement you can buy right now that you can store. We cannot carry the present cement in stock as long as the old cement. We have not found that we can avoid cracks in our concrete structures. A great many things are showing up in the new cement on which we have to have an answer. We cannot get it except through our own experience, as it stands now. Certainly, it is fitting that the committee should make a study on that subject.

Chairman Leonard: I will attempt to answer both Mr. Westfall and Mr. Leffler. Subject c, under Progress in the science and art of concrete manufacture, is a live subject of Committee 8. We have presented no report on it this year, but expect to prepare a report on the subject during the current year.

On the broader subject of cements of all kinds, I refer you to assignment No. 13 "Progress in cement manufacture and testing" which is in the hands of an active subcommittee, that has a report in preparation. Committee 8 is not unmindful of the cement problem which all engineers have in front of them. It has already recognized the fact in requesting assignments from the Committee on Outline of Work, and it is the intention to ask for further assignments along the same lines.

Vice-President Hastings: This portion of the report is received as information. The chairman's explanation I think clears up the two points which have been raised.

Proceed, Mr. Leonard.

Chairman Leonard: The next item is No. 4 which is Maintain contact with Joint Committee on Concrete and Reinforced Concrete. Your Association, through Committee 8, has three representatives on the Joint committee, Mr. Hirschthal, chairman of the representation, Mr. Walter and the speaker. As Mr. Hirschthal was unable to be present, I will present the report on the subject.

The committee is active and has prepared a preliminary report, and it is still hoped that, before the current year is over, a final report of the Joint Committee on Concrete and Reinforced Concrete will be published. This report is offered as information.

Vice-President Hastings: It will be so received, Mr. Chairman.

Chairman Leonard: The next assignment is that of Specifications for foundations, including excavation, cofferdam, piling, and so forth. I will ask Professor Vawter, who is chairman of this subcommittee to present the report.

Professor Jamison Vawter (University of Illinois): The report of the subcommittee on Foundations is given in Appendix D on pages 418 to 424. A few changes have been made in Sections I to V. These specifications were submitted last year as information with the intention of revising them during the year for publication in the Manual.

Section VI was submitted only in outline form last year, and therefore as published in this report is essentially new material. For that reason Sections I to V, inclusive, are recommended for adoption and publication in the Manual, while Sections VI, VII and VIII are submitted as information. It is our intention to submit them for publication in the Manual next year.

There have been a few minor changes in the first five sections since last year. In Section II, the last clause has been added to the first paragraph. In Section III under Design, earth pressure has been added to the primary forces under Loads. I believe Mr. Leffler made that suggestion last year.

In paragraph 2, Increased load on piles, the sentence referring to earth pressure was eliminated. That referred to earth pressure being included under the primary forces. In paragraph 5, Uplift on piles, the last clause was eliminated. In Section IV, paragraph 5, the clause "unless limited by other determined pile capacity" has been added, and in paragraph 7 there have been some minor changes in the phrasing, also minor editing in Section V, paragraph 4.

On page 420 we would like to make a small change in the wording. Section IV, paragraph 4, change the wording at the end of the sentence to read "nor shall the allowable compressive stress in the pile material be exceeded."

I move that Sections I to V of the Specifications for pile foundations be adopted for publication in the Manual.

(The motion was seconded.)

Mr. Westfall: Under Section 2, Purpose and necessity, I find the statement, "Pile foundations may be used when the bearing power of the soil is insufficient." I do not get the meaning of the expression "may be used." I wonder if that means just what the committee intended. It sounds as if it is permissible to use them. It seems to me it is about the only thing that can be done. I wonder if a different word might not be better employed.

Professor Vawter: You would suggest "shall"? Other types of foundations might be used, might they not, Mr. Westfall?

Mr. Westfall: Creosote, but that does not come under this section.

Professor Vawter: Mat foundations and other types might be used.

Mr. Westfall: It sounds to me as though you don't have to use it, you can float the foundation on what is there, or you may put it on piles. If it really carries the thought that the committee has, I will not object, but I question whether the word "shall" is right. So far as I see it, pile foundations are properly used in such-and-such case, or the object of them is for use in such-and-such cases.

Professor Vawter: It is the sense of the committee there are other types that can be used when the bearing power of the soil is insufficient.

Mr. Westfall: I defer to the committee.

The second paragraph is not clear to me; I refer to "less firm substrata." It says: "Depending upon subsoil conditions, piles consolidate the soil and transfer the load to less firm substrata by skin friction." Does not that mean substrata that is less firm than the consolidated soil, or that is necessarily less firm than the surface soil was originally? It might be the same type of soil all the way down, or the soil below the points of the piles might be a little bit more firm than that into which the piles were driven, but not hard enough to call it hard substrata.

Professor Vawter: It is the sense of the committee, where you have less firm substrata, that the pile will consolidate the soil and transfer the load to it by skin friction or, where you have a hard substrata, the piles will carry the load to the hard substrata below.

Mr. Westfall: The expression "less firm" does not mean it would be less firm than what it is going through.

Professor Vawter: It would not be less firm than what it is going through. It could be compared to something that might be somewhat else, possibly.

Mr. Westfall: The word "less" is not intended in that way?

Professor Vawter: Not necessarily in that vicinity.

Vice-President Hastings: Any further discussion? The question is on the adoption of the specification.

(The motion was put to a vote and carried.)

Professor Vawter: The next part, Sections VI, VII and VIII, is offered as information. Section VI covers Types of piles and embraces Class (A) Timber; Class (B) Concrete, divided into Pre-cast and Cast-in-Place; Class (C) Steel, divided into H-Sections and Pipe Piles; and Class (D) Composite Piles. There has been no change in Section VII as it was printed last year, but since Committee 7 is reporting on specifications for driving wood piles, this committee desires further collaboration with Committee 7 on the subject of driving.

The committee will be very glad to have any suggestions or criticisms regarding these last three sections, as we expect to resubmit them next year for inclusion in the manual so as to have a complete set of specifications for pile foundations. These last three sections are offered as information.

Vice-President Hastings: Is there any discussion? They will be so received.

A

Chairman Leonard: The next subject is Methods and practices of lining and relining tunnels. Mr. I. L. Pyle, chairman of this subcommittee, will present the report.

Mr. I. L. Pyle (Chesapeake & Ohio): The report of this subcommittee is found on page 424. I shall only read the last sentence in the prefatory paragraph. "This preliminary report sets forth the various types of tunnel lining that will be considered in subsequent reports on lining and relining tunnels." This is offered as information.

Vice-President Hastings: Is there any discussion: It will be received as information, Mr. Pyle.

Chairman Leonard: The next subject is Specifications for placing concrete by pumping, and I will ask Mr. Pyle, who is chairman of this subcommittee to present this report.

Mr. Pyle: This report is found on page 426. It is a specification for placing concrete by pumping and I shall read only the headings. The first part is Scope. Following this is Operation, describing somewhat in detail the several methods by which the concrete can be placed, and the type of equipment. The fourth section refers to mixing and proportioning of concrete. The last is a recommendation as to the use of duplicate equipment.

I move that this report be accepted for inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Leonard: The next assignment is one of long standing, Review specifications for overhead highway bridges of the American Association of State Highway Officials. The committee has no report to make on this assignment, or on the next subject, Rating of reinforced concrete bridges.

The next subject is, Investigation of the merits of the vacuum method of treatment of concrete after placement. I will ask Mr. Robinson, chairman of this subcommittee, to present the report.

Mr. G. E. Robinson (Cleveland, Cincinnati, Chicago & St. Louis): The report of this subcommittee is found on page 427. This committee has had this subject for two years, and has studied the available literature. The subcommittee also visited a laboratory of one organization that sponsors this process, and saw a demonstration which included the pouring of a small slab 3 in. thick, 3 ft. by 4 ft. which stood on edge after the vacuum had been applied for a matter of ten minutes, and the concrete was so hardened that a man stood on the edge of it without collapsing it or even leaving footprints. The vacuum mat that was used for that demonstration had a celluloid backing so that we could see the action. It was very interesting.

We have been furnished with some preliminary tests that were made by a neutral laboratory, and these indicate that this process will probably show 20 percent less volume change, 30 percent increase in strength, 40 percent decrease in absorption over ordinary wet cast units which are molded without vibration. The last part of the report gives the sponsor's claims which we set forth here without supporting them in any way. We are unable to furnish any cost figures that are worth printing. Because we have not been getting very much co-operation from the sponsors, we are disposed to discontinue the subject, at least for the next year.

This report is offered as information.

Vice-President Hastings: Is there any discussion? The report will be received as information.

Chairman Leonard. The next assignment is Study and investigate the suitability of steel-beam bearing piles. This has already been covered as a part of our report on foundations. Another assignment is Progress in cement manufacture and testing. We

are fortunate in having a very active chairman of this subcommittee, and we do hope to give you some real information on the subject later.

The next assignment is Specifications for concrete culvert pipe. In the absence of Mr. Doll, the subcommittee chairman, I will ask Mr. Laird to present the report.

Mr. Laird: The report appears on pages 429 and 430. Specifications for reinforced concrete culvert pipe, conforming to ASTM serial designation C–76–37 were previously adopted by the Association. However, the subject matter contained in this report has in mind information for the engineer who must determine whether some particular pipe is suitable to bear the loads which will be transmitted to it, in cases where previous information has not been available and where the manufacture has not been directly in accordance with the ASTM specifications. This subject matter was presented at the last convention as information in substantially its present form, and, eliminating the first paragraph on page 429, which is largely explanatory, the remaining subject matter to the bottom of the page, including the table on the following page, is submitted for adoption and printing in the Manual, and I move that it be so adopted.

(The motion was seconded.)

Mr. Westfall: I am wondering if the committee is going to make some recommendations as to which design of pipe is to be used for certain conditions. I do not have the ASTM specification before me, but I believe there are two tables and possibly two strengths of pipe in each table. We are put at somewhat of a disadvantage now in specifying a pipe for work in which public authorities are involved, if we are to use the ASTM specifications by picking out of them a particular type of pipe, without any recommendation from any other body as to the proper strength of pipe to use.

If I am correct, it seems to me it would be well for the committee to give some recommendation, something definite to guide us. The same situation prevails with respect to corrugated metal pipe. Some five kinds of pipe are covered by the specifications, without any restriction at all, and it puts us in a bad light when we pick a particular type without some backing.

Mr. Laird: That particular question does not have direct reference to this year's report. Mr. Westfall is referring to subject matter which was adopted in the former year. Ordinarily it was intended that the matter would be discretionary with the engineer, inasmuch as the engineer might wish to adopt one specification loading for one case and a different specification loading for a separate case.

However, we do not think that matter is before us now as a part of this report. If it is to be reported on, it would have to be considered further by the committee.

(The motion was put to a vote and carried.)

Chairman Leonard: The members of this committee, individually, read a lot of engineering literature relating to the subject of "Masonry", but have come to the conclusion that, as a group, they were missing much valuable information. For that reason they organized a subcommittee to review current engineering literature of particular interest on railroad masonry work and to present summaries of this matter to the entire committee from time to time.

As the committee felt that this information would be of value to others, the Committee on Outline of Work was asked to authorize the publication of these summaries as a part of the report of Committee 8. We are fortunate in having a chairman of this subcommittee, Mr. Coburn, who has reviewed a large amount of engineering literature. I will ask him to present the current report which deals with the prestressing of reinforced concrete.

(Mr. Maurice Coburn (Indianapolis, Ind.), the subcommittee chairman, then read a number of excerpts from the report, which was accepted as information.)

Chairman Leonard: It is with profound regret that Committee 8 has to record the death of Mr. Lauritz Walter Skov, a very valuable and active member of our committee.

Mr. Chairman, that completes the report.

Vice-President Hastings: The report brought to us this year by the Committee on Masonry is, again, a very splendid one and shows a tremendous amount of hard work. The committee is excused with the thanks of the Association. (Applause)

DISCUSSION ON ELECTRICITY

(For Report, see pp. 71–74)

(President Morrow presiding.)

Chairman H. F. Brown (New York, New Haven & Hartford): Forty years ago, when this Association was founded, there was no Committee on Electricity. The engineering staffs of the railroads who founded this Association, which has been of great value to the transportation industry, did not include electrical engineers. Since that time, I think it goes without saying, electricity has played a greater and greater part not only in our everyday life but in our transportation industry, so that there is hardly a phase of the transportation industry that is not affected by the application of electricity. It is for this reason that your Association has had a Committee on Electricity for a number of years.

Out of that committee has grown eventually the Electrical section of the Engineering division of the Association of American Railroads, and, in addition to this particular activity, the Association of American Railroads has a T. & T. section of the Operating division, and the Electrical section of the Mechanical division, all dealing with the particular field of the application of electricity to the operation of railroads. It is in connection with the activities of the Electrical section of the Engineeering division that your committee is reporting today, together with the improvements and increase in the application of electricity to the railroads in general.

(At this point Chairman Brown presented the substance of the subject matter under Developments in Application of Electricity on pages 71 and 72. He then reviewed the reports of the Electrical section committees, which were published in full in Bulletin 405, September–October, 1938. His comments supplementing the matter on pages 72 and 73 were as follows:)

Mr. Brown: The Committee on Overhead Transmission Line and Catenary Construction is working on wire crossing specifications and in that connection, has made considerable progress with the Edison Electric Institute in formulating standardized practices in connection with such crossings. It is also working with subcommittees of the American Standards Association in bringing about a revision of the National Electrical Safety Code, and considerable progress has been made during the past year in this work, pending the completion of which the crossing wire specifications will be held up until certain standards have been decided and agreed upon.

The Committee on Electric Heating and Welding has reported a comprehensive procedure for the application of electric heat for reconditioning flood damaged equipment. Every year because of floods and disasters such as hurricanes, we are finding more and more the need for standardized practice in reconditioning important electrical equipment that has suffered damage from water.

Last year the Committee on Clearances for Third-Rail and Overhead Working Conductors completed what it believed was a proper overhead clearance diagram for the working conductors, but because of certain objections approval for its publication in the Manual was withheld. Subsequently, a revised diagram designed to overcome these

objections was presented to the section for approval by letter ballot, but I learned at the meeting of this committee yesterday that there were still certain objections to this clearance diagram. Accordingly, the work will have to be continued, and it is hoped that compromises can be made which will bring this diagram into line for inclusion in the Manual next year.

In connection with the report dealing with protective devices and safety rules in electrified territory, the committee has continued its work, in collaboration with the Signal section, on a revision of Circular ES 3, dealing with the safe handling of inflammable liquids, to prevent fires due to electric sparks, which will be satisfactory not only to the railroads but to the American Petroleum Institute. A great deal of progress has been made, and it is thought that this new standard procedure will be ready for adoption within the very near future.

The Committee on the Application of Corrosion Resisting Materials to Railroad Electrical Construction has also continued its work, although it has not submitted anything but a progress report this year. The committee has done a very valuable amount of research work in connection with the study of suitable materials which will withstand atmospheric corrosion, particularly in the presence of smoke, such as we have around the railroads.

The report also includes a memoir in appreciation of the work of Mr. Loren S. Wells of the Long Island Railroad, who retired this past year, for many years a very valuable member of the AREA Committee on Electricity and also of the Electrical section. It also includes memoirs of Messrs. George W. Bebout, Joseph W. Foote and Harry C. Goodrich, active members of this section and of the AREA, who died during the past year.

The report is respectfully submitted as information.

President Morrow: Mr. Chairman, I wish to express the appreciation of the Association for your excellent resumé of what is being done. The committee is excused with the thanks of the Association. (Applause)

DISCUSSION ON ECONOMICS OF RAILWAY LOCATION AND OPERATION

(For Report, see pp. 83–181)

(Vice-President Hastings presiding)

Chairman H. M. Stout (Northern Pacific): During the past year your committee has given consideration to the 13 subjects assigned to it, and reports on 11 are offered here. Although no conclusions for publication in the Manual of Recommended Practice nor revisions of present matter in it are offered in this report, the presentations on seven of the subjects are preliminary to such action. Many of these subjects are highly technical and discussion of the reports is urged, and offers of information and material related thereto are solicited for use in further treatment of the subjects.

The first subject to which our attention has been devoted is Revision of the Manual: Section XVI of the Manual contains the adopted conclusions related to the Economics of Railway Location. It is divided into the following two mutually related groups: I. Economics of Railway Location, relating to the basic principles of the general layout of a railway, or of an economic transportation-by-railroad plant, the revision thereof and improvements thereto, and II. Power. Two years ago the first progress report of a thorough review of the second section, II. Power, was presented. This was continued in the report offered last year, and it is completed in the report here given in Appendix A.

Mr. E. E. Kimball, chairman of the subcommittee, will present the report.

Mr. E. E. Kimball (Schenectady, N. Y.): The report of the subcommittee, which appears on pages 84 to 122, consolidates and condenses two previous reports which described methods for computing the speed, tractive effort and horsepower characteristics of steam, electric and oil-electric locomotives and is intended to be a ready reference with fuller explanations and examples than would be feasible in the Manual.

The purpose of these methods is to provide a comparable basis for estimating the performance and fuel or energy consumption of various types of locomotives over any fixed profile or alinement in order to study their economic value.

Actual design data for this purpose are seldom available because in most cases the final designs will depend upon conditions developed from preliminary studies. In other words, the methods described in the report make it possible to study the characteristics which are necessary to obtain the desired results. Then the problem is one for designing engineers and locomotive builders to fit their designs to meet the desired characteristics or adjust the final characteristics to fit their designs.

The important characteristics which need be considered in these preliminary studies are weight, tracking qualities and horsepower capacity. These conditions or characteristics generally determine the wheel arrangement required or, vice versa, the wheel arrangement fixes the conditions. This is particularly true in the case of steam locomotives which adhere to a few conventional wheel arrangements as indicated in the tables on pages 87 and 89. In the case of electric and oil-electric locomotives, it is possible to use a large variety of wheel arrangements and for this reason it is necessary to adopt a different system of classification than the one used for steam locomotives. The system usually adopted for electric and oil-electric locomotives is explained in the report.

There is another important difference between steam and electric or oil-electric locomotives which needs mentioning. In the case of electric locomotives, power is obtained from an outside source of practically unrestricted capacity and the amount of power used is inherently determined by the characteristics of the locomotive. In the case of oil-electric locomotives, the amount of power used is limited to the capacity of the power unit by an automatic control. In both of these cases the power used may be and generally is independent of the operator, consequently it is possible to estimate the performance and fuel or energy consumption very closely.

In the case of steam locomotives, there are no automatic features and the power developed depends upon the rate of firing and the manner in which the locomotive is operated. This makes it more difficult to estimate the performance and fuel consumption of steam locomotives than it is for the other two types.

To avoid this difficulty, the committee has attempted to establish a normal horsepower capacity for estimating the performance and fuel consumption of steam locomotives which would correspond to the engine rating of oil-electric locomotives. For this purpose it assumes that the normal capacity is fixed by a uniform firing rate which is equal to one-half the rate that corresponds to maximum evaporation.

This is equivalent to defining the normal capacity as equal to three-fourths of the maximum capacity due to the fact that the boiler efficiency is much better at the lower firing rate than it is at the higher rate. This explanation is necessary in order to reconcile the horsepowers obtained from the table on page 89 with the published horsepowers obtained in tests.

The chart on page 98 shows a comparison between the maximum and normal characteristics of typical steam locomotives. Fig. 3, page 97, shows speed-time and energy-consumption curves based on these characteristics. A comparison of the normal and overload performances based on a 25-mile run is given in the table at the top of page 100.

The material contained in the sections on electric and oil-electric locomotives is largely a repetition of that contained in previous reports, except that the equations for direct-current and single-phase alternating-current locomotives on page 102 have been added, because in some cases it is easier to substitute in the formulas than it is to depend entirely on the forms.

This report completes the study of various types of motive power in relation to the subject of Power (Section II in the Manual) and explains the development and application of various forms for calculating typical characteristic curves of the principal types of locomotives. It is assumed that the forms, with brief instructions in regard to their use, will be sufficient for Manual purposes if reference is made to this report and those in the Proceedings, Vol. 38 and 39, for a full discussion of the basic principles.

Because of its length, the report is offered as information and not for inclusion in the Manual. The committee will welcome any discussion to guide them in preparing material for inclusion in the Manual next year.

Vice-President Hastings: Is there any discussion of this part of the report that has been presented by Mr. Kimball? It certainly represents a tremendous amount of work on the part of the committee.

Chairman Stout: You may expect next year to be called upon to approve the substance of what has been presented by Mr. Kimball, in proper form, for that which is now in the Manual under Section XVI, Part II.

The second subject is Methods for obtaining a more intensive use of existing railway facilities. Notwithstanding the 12 progress reports which have been offered, this is a subject of real present interest to the railways. The report of information (Appendix B), will be presented by Mr. L. E. Dale, chairman of the subcommittee.

Mr. L. E. Dale (Association of American Railroads): The report appears on pages 123 to 129, and is concerned this year with the question of joint use of facilities owned by one railroad by another line, generally referred to as Joint Facility Use, covered by agreements. It reviews briefly the extent to which joint facility use was in effect at the time of the latest survey, and the further development of the joint-use idea during the period of declining business for the past eight or nine years. It covers, also, the progress made under the federal co-ordinator in respect to studies of joint use by the co-ordinating committees, and the progress made in the re-study of co-ordination projects affected by the labor provision of the Transportation Act, which were studied but on which no action was taken by the co-ordinating committees. These are now being re-studied by committees of the Association of American Railroads. The report is presented as information.

Vice-President Hastings: Thank you, Mr. Dale.

This is a matter that I am sure has concerned practically all of you. The committee has presented a very splendid report. It is worthy of very careful study. It will be received as information if there is no discussion.

Chairman Stout: Subject No. 3, Methods or formulas for the solution of special problems relating to more economical and efficient railway operation. A considerable number of special problems have been discussed in reports presented under this assignment since it first was given to this committee. The topic selected this year, a report on which is offered as information, has to do with the economic relation between the track structure and the traffic to be handled. Mr. C. H. R. Howe, chairman of the subcommittee, will present the report, which is included as Appendix C.

Mr. C. H. R. Howe (Chesapeake & Ohio): In the course of this investigation the performance records of 93 railways, covering the 10-year period 1927-1936, inclusive, were

considered by the committee. Certain of the comparative results obtained are given in the tables included in the report. Examination of the figures given quite definitely confirms the prevailing opinion that an improved track structure not only results in lower maintenance costs, but permits greater reductions in expense in times of necessity.

Mr. President, this report is presented as information, and we are recommending that this subject be continued. The subcommittee will be very glad to receive any comments or suggestions from the members indicating along what lines further investigation should follow.

Vice-President Hastings: Thank you, Mr. Howe. I had hoped that you would talk a little longer on that subject. A tremendous amount of work is represented by pages 130 to 144, inclusive. The information is of great interest. Is there any discussion of this part of the report?

Mr. J. C. Irwin (Boston & Albany): It seems to me that some of these reports that are presented as information might very well be elaborated a little from the rostrum to give the members present a better idea of what they contain. Even though we have read them, those who prepared and studied them have certain points in mind that could very well be emphasized. This committee was allowed only 30 min. on the schedule, and we are 40 min. ahead of time. Personally, I should like to see the committees give considerable time to pointing out the salient features of these reports even though they are submitted merely as information.

Chairman Stout: Subject No. 4, The effect of volume of traffic on railway operating expenses. Heretofore four reports have been presented on this subject. These are referred to in a brief report included as Appendix D. I think the chairman of the subcommittee, Mr. Fairweather, is not present. In his absence I will make a very brief presentation of the summary that has been prepared for your consideration. This subject was first assigned to former Committee 21 in 1931, and reports were submitted to the conventions in 1932, 1934, 1936 and 1937. In these previous reports consideration was given to the analysis of statistical data applicable to Class 1 railroads of the United States with reference to factors underlying fluctuations of operating expenses that have a casual relation to traffic density, while tables, diagrams, equations and examples were presented showing the methods used to determine the effects of traffic density on operating expenses. Tables were given showing the proportions of transportation expenses that are variable at indicated levels of traffic density corresponding with the three districts of Class 1 railroads. And, finally, in the last report, by means of equations and charts, a simplified method of arriving at the effect of traffic density on operating expenses was developed. Further study of the subject is being pursued by the committee and a report completing the exposition, the discussion of all factors involved, and the presentation of concise conclusions is planned. This report and review are presented as information.

Subject No. 6, Effect of inland waterway transportation on the economics of railway operation. This is a new assignment and one of deep interest and broad significance to the railways at this time. It is a large subject. An introductory report of information (Appendix E) is given. Mr. J. E. Teal, chairman of the subcommittee, will present the report.

Mr. J. E. Teal (Chesapeake & Ohio): As stated, your committee proposes to present a number of reports of which this one comprises a brief history of the development of inland water transportation in the United States as related to the development of railway transportation. It should be carefully read to understand fully the seriousness of the problem as it relates to the economics of railway operation.

(At this point, Mr. Teal directed attention to some of the more prominent features of the report.)

Mr. Teal: I desire, also, for a few moments to discuss in a broad way the effect these inland waterways have on the railroads, and I will present the views of men well qualified to speak on this subject.

Inequality in our public transportation policy is one of the factors affecting today's transportation difficulties. They include inequality in regulation, inequality in taxation and inequality in subsidies.

These inequalities directly or indirectly affect every citizen, every shipper and every community. They penalize one community and favor another. They penalize one shipper and favor another. They have brought about abuses far more widespread and serious than those which the Interstate Commerce Act, now over fifty years old, was designed to correct. They foster discrimination and favoritism and have contributed in no small measure to increases in the unit cost of railway operation and to the breakdown of railway earnings, railway credit and railway purchasing power.

It is difficult to understand why railway investors and railway employees, such as are represented by the members of the American Railway Engineering Association and more particularly the leaders of organized railway labor, have not taken a more definite stand against policies of the state and national governments, where these policies have resulted in reduced railroad employment and favored other transportation agencies.

These inequalities may be briefly illustrated as follows: Between two cities, more or less paralleling each other, is a waterway, improved and maintained by the federal government; a highway, built and maintained with public funds; and a railroad, built by private capital and maintained out of operating revenues. Each of these three transportation facilities represents a large investment of the American people. Capital required for building waterways and highways is raised by means of taxes and in the case of the railways, by private investments.

The waterway is not required to earn a return upon its investment. The locks, dams and connecting channels are maintained and operated with tax funds, and the facility itself is exempt from taxation. The commercial users of the waterway, competing with the railroads, are thus provided with a tax-free roadway, built and maintained at public expense. Such users contribute nothing whatever in tolls or other charges toward its cost or its upkeep.

The highway, like the waterway, is not required to earn a return upon the capital required for its construction. Tax funds are used to repair and police the highway, and the property is also exempt from taxation. Commercial motor trucks and buses which operate on the highway pay certain fees and taxes which, generally speaking, fall far short of meeting their share of the actual highway costs incurred for their benefit; thus a part of the highway cost incurred by commercial users is borne by the taxpayers. In this connection studies made by the state highway authorities of Illinois and Missouri indicate that commercial users of the highways operating vehicles having truck capacity in excess of one ton pay substantially less than 50 percent of the total highway costs. The fact that these transportation facilities are tax-exempt simply means that all other property must pay more taxes than would otherwise be necessary.

On the other hand, the competing railroad as you know is on a self-supporting basis. No part of its cost is borne by the taxpayers. The railroad must earn a return upon its investment in lands, roadway and other fixed property, as well as upon its equipment in order to remain solvent. The cost of maintaining roadway and equipment must be met by the railway company out of earnings. Earnings must also be sufficient to pay large sums in taxes each year for the general support of government.

The waterway operator usually owns and maintains merely the equipment which he uses; he often uses public-owned terminal facilities which are not taxed or required to

earn a return on the investment. While the competing railroad owns, maintains and pays taxes upon the right-of-way and roadway, as well as equipment.

On page 152 of the report, your committee calls attention to a statement of President Roosevelt when, on August 18, 1938, at Kingston, Ontario, he said:

"We know now that the effect of a waterway is not to take traffic away from railroad lines. Actually, it creates new possibilities, new business, new activities. Such a waterway generates more railroad traffic than it takes away."

We shall revert to this in future reports, in which an analysis of the traffic created and transported will be made, and the economic justification of a number of inland waterway projects will be studied. Twelve projects are listed, to which your committee wishes to add as No. 13, the Panama canal and No. 14, the Florida ship canal.

Time will not permit an extended discussion on any one of these projects now. However, I will point out one example which should be sufficient to satisfy the average person, that it is very much against the public interest for federal authorities to continue to spend large sums of money for subsidized transportation, and that it would be only proper and fair that, where such facilities have been provided, the users should be required to pay a fair charge, in the way of tolls or taxes, sufficiently to meet the costs now borne by the general taxpayers.

Ohio River improvements for navigation between Pittsburgh, Pa., and Cairo, Ill., including the construction of 47 locks and dams, have cost the taxpayers of the United States an average of $141,954 a mile, most of which has been spent in the last 15 or 20 years. Measured by the same yardstick required of railroads, the overall annual subsidy per river mile on this improvement is about $10,896, divided $5,678 for interest at 4 percent, $4,125 for maintenance and lock operation, and $1,093 for taxes.

Traffic on the Ohio, consisting mostly of coal, iron and steel, sand and gravel, petroleum and other low-grade bulk commodities averaged 2,709,775 ton-miles per mile of waterway in 1936. The total river cost per ton-mile is about eight mills of which four mills is paid by the general taxpayers and four mills is paid by the shippers. The river distance is about 1.53 times the rail distance; therefore, the river ton-mile cost is equivalent to a rail ton-mile cost of 12.2 mills, which compares with an average rail revenue of approximately ten mills for all commodities.

Although transportation on the Ohio river can probably be economically justified to a greater extent than on other inland waterways, of the total water cost, 50 percent is borne by the shippers and 50 percent is borne by the taxpayers. Waterway transportation may be cheap to the favored shipper, but it is costly to the taxpayers who foot the bill for improving, operating and maintaining the locks, dams and channels.

I will quote Mr. Thomas F. Woodlock, former member of the Interstate Commerce Commission. This might well be considered by each member of the Association.

"The real question before the people is whether they shall continue to tax themselves to provide for a small proportion of their number, water transportation for less than it cost and, incidentally, furnish unfair competition for the railroads."

The report is presented as information, and your committee hopes to pursue this subject during the coming year, keeping in mind the seriousness presented by subsidized transportation, trusting that each member will take it upon himself to do something about it.

Vice-President Hastings: Is there any discussion of this part of the report?

Mr. W. J. Burton (Missouri Pacific): First I want to call attention to Table 4 on page 157. I believe that the headings of these two columns should be "Thousands of Short Tons" and Thousands of Dollars of Declared Value." As the figures stand, they do not correspond with the figures given in Table 5.

Mr. Teal: Mr. Burton, you are correct. Three ciphers were inadvertently omitted.

Mr. Burton: The principal thing I want to speak of is a point which was not mentioned by Mr. Teal in the statement of the comparison between river costs and railroad costs, and I believe it is very important. In practically every case where river transportation is in use, railroads are an essential part of that transportation. Railroads bring the traffic to the river, and then, in many cases, take it from the river terminal to the point of final destination. This is more true on some rivers than on others. On the Ohio river it is true to a lesser extent, perhaps, but it is still true.

Now, the effect of river transportation is to cause the railroads to reduce their rates, generally about 20 percent. We have on our railroad a great deal of territory covered by joint river-and-rail rates which are lower than all-rail rates. The railroad is a necessity even for transportation by river, and leaving out the question of minor branch lines, it can be said generally that railroads are a public necessity and, therefore, must be continued.

There is no place from which this cut of 20 percent, or whatever the cut in rates is that is made necessary by river competition, can be made up, excepting, in the long run, by an increase in rates to non-river points or points which are not benefited by the river competition. So the net effect, as far as the general public is concerned, is to shift the load from the portion of the shipping public fortunate enough to be along the rivers to that portion of the shipping public which is not along the rivers. It is merely a transfer of the cost of railroad transportation from one part of the public to another, and it doesn't benefit the country as a whole.

This is an entirely additive argument against most river transportation, that is, in addition to the one that only a portion of the cost of river transportation is borne by the river rate-payer. I think it is a very important point.

Mr. Teal: I thoroughly agree with Mr. Burton. As a Chesapeake & Ohio employee, I had not expected to discuss this phase of the problem, but since it has been brought up I might say that we haul from the mines in West Virginia to Huntington, a distance of 100 miles, about 1,500,000 tons of coal annually. It is dumped into barges, floated down to Cincinnati (about 160 miles, by rail). There, the bulk of it is used locally in the Cincinnati area; however, a large amount is picked up and put into railroad cars and moved to other destinations, such as Indianapolis. Such an operation is, obviously, inconsistent with sound economic principles.

We publish a depressed rate to Cincinnati because of river competition. In other words, our rail rates to Cincinnati are not normal, standard rates that would ordinarily apply where river competition does not exist.

We publish a very much depressed rate to the Huntington tipple, because a number of mines are located right on the banks of a navigable river tributary to the Ohio; some of the mines, of course, are not. Therefore, in order to make everything equal, we have to reduce rates from interior mines not favored by the river, so they can all get a proper share of the markets.

Mr. W. D. Faucette (Seaboard Air Line): What Mr. Teal said is very interesting. I would like to add for the benefit of your committee, in reference to its proposal to take up the question of the "Cross-State" Florida canal, that the Association of American Railroads will this week present to the Senate and House committees in Washington, if the time is reached, a complete presentation on the engineering, geological and traffic features of this canal. A railroad committee has devoted a great deal of time for several years in compiling a vast amount of information regarding this project.

I might say that if that canal is built, it will probably be one of the greatest canals ever constructed in the history of the world. It would be about 200 miles from end to end, with a net width of 400 ft. and, according to our figures, it would cost about one-

third of a billion dollars. One section of that canal will require more excavation than has been done on the entire Panama canal. When these figures and the accompanying statement have been presented to the Senate and House, they will be available to your committee for a complete review and I believe the data submitted will be of interest.

Mr. F. R. Layng (Bessemer & Lake Erie): I want to emphasize that the threat from this source of competition seems to be increasing.

We at Pittsburgh are now very much concerned over a favorable report just made to the secretary of war recommending the construction of a canal to connect the Ohio river at Rochester, Pa., with Lake Erie. One of the significant comments in the report of General Schley is that, if the railroads will lower their rates 29 cents per ton, there will be no justification for the construction of the canal. In other words, I am wondering whether or not this is a bona fide or a sincere proposition, to build a canal. Are they not simply using this as a club to beat down railroad rates?

Mr. Faucette emphasized the size of the canal proposed in Florida, and its cost. Here, again, in the Pittsburgh area, we are faced with the threat of a $300,000,000 expenditure of public funds that would take away from the railroads in that area a very important volume of traffic if the canal is built and used. Many of the phases of this Ohio proposition have not been explored.

I think I am correct in saying that the craft necessary to operate on the canal have not been designed. There is no definite or concrete proposition as to how the north port on the south shore of Lake Erie will be operated, and who will operate it. The government simply creates the port by building breakwaters and doing essential dredging. The canal is proposed to be built at a depth of 12 ft. and yet much of the Ohio system is only 9 ft. in depth, so that the interchange of traffic between the two units of one system will present complications that are not worked out in detail at all.

This brings me to the comment that it is a strange thing that our Board of Engineers will bring in a favorable report on projects as large as these and yet many of the essential features have not been studied in detail, and no one knows how they will be finally worked out.

One other phase of the Ohio situation is that it contemplates that those who would use the canal, would furnish the craft, and the terminals at their plants to make the transfer from water to their mills or to rail. None of these prospective users has in any way given the government a sound or binding commitment that he will use the facility if it is built.

Certainly, it is another illustration of wild spending and crooked thinking all along the line, but having for its net result a serious threat to our industry.

Chairman Stout: The next subject is No. 7, Effect of high speed on railway operating expenses. This, also, is a new subject. A progress report of information is given as Appendix F. Mr. M. F. Mannion, chairman of the subcommittee, will present the report.

Mr. M. F. Mannion (Bessemer & Lake Erie): The subcommittee report is on pages 165 to 166. It lists the general divisions of railway operating expenses and those general divisions which will not be affected by high speeds. Information now available in connection with maintenance of way and maintenance of equipment expenses is entirely too meager to give any definite idea of how much expenses will be affected by high speeds.

The committee has started a study of transportation expenses which embraces an examination of train speeds for a period prior to and subsequent to the initiation of high-speed trains, in an attempt to determine the effect of high-speed trains on other train operations. This is a progress report and is offered as information.

Vice-President Hastings: You have heard the statement of the chairman of this subcommittee. Is there any discussion on this part of the report? If not, it will be so received.

Chairman Stout: Subject No. 8, Effect of rail oiling on train operation. This is another new assignment to this subcommittee, and an introductory report of progress is offered in Appendix G. Since publication of the report, a considerable amount of opinion data from the experiences of a number of railways using rail-wheel flange lubricators has come to the committee. However, the committee is seeking more information and specific data that any member may have relating to this subject, which he feels he may give the committee for use in this study.

Mr. J. A. Parant, chairman of the subcommittee, had not expected to be here today, so I will present the report for him. This subject is presented in Appendix G, beginning on page 166 and continuing to 168. It is a brief resumé of the work that has been done and reports that have been prepared and given to this Association by other committees, and it also outlines the study to be made in the future.

Passing from Subject No. 8, unless someone has something to contribute to this study, the next subject is No. 9, Compile operating data essential to establish units for making line and grade revisions to meet operating requirements.

Although this subject was placed on the agenda of the committee in 1928, only one previous progress report has been published on this subject. That was given to the convention of 1936, and published in Vol. 37 of the Proceedings. A brief discussion of the assignment is included in this report as Appendix H. No conclusions for publication in the Manual are given, but the subject is an important one, and parameters of use in guiding decisions in case of contemplated revisions of line and grade should be made available from the conclusions of the study.

Mr. J. M. Farrin, chairman of the subcommittee, will present the report with such supplementary discussion and comments as he may find appropriate.

Mr. J. M. Farrin (Illinois Central): The report of Subcommittee 9 is offered as information only. It lists in concise form items in both the present and proposed operation that should be known in order to determine whether a proposed improvement is justifiable from an economic standpoint. Items entering into the expense are discussed in the body of the report, and certain expense information relative to some of the items given to assist in making the comparison. This information is given as a guide only, and, if information more applicable to the improvement is available, it should be substituted.

At the conclusion of the report is a statement showing in parallel columns selected items of expense that enter into the annual cost of both the present and proposed operation. The summation of these two columns, when filled in, will give the necessary information as to whether the proposed improvement is economically advisable.

Vice-President Hastings: Thank you, Mr. Farrin.

Is there any discussion of this portion of the report? Proceed, Mr. Stout.

Chairman Stout: Subject No. 11, Spirals required for high-speed operation. A first progress report on this subject was offered last year. A final report, with conclusions for the Manual, had been planned for presentation at this time, but some new material and discussion came to the committee too late to be thoroughly explored and digested; therefore continuation will be asked.

Mr. H. M. Shepard, chairman of the subcommittee, is unable to be present today, and has arranged with Mr. O. E. Selby, a member of the subcommittee, to present the report in his stead.

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis): The report begins on page 172. The first three pages are historical. The use and development of transition curves is traced back to the beginning, in 1895. In 1921 the use of such curves was practically universal with the railroads. This Association has been struggling with the problem since the second annual convention in 1901. The various reports on the subject have been described in this report.

Committee 5—Track has presented at various times formulas and tables for transition curves, and the subcommittee has taken the work of the Committee on Track as a starting point for the matter presented in this report. The starting points are: (1) The use of 3 in. unbalanced superelevation as fixing the permissible speed, (2) the use of 1¼ in. per sec. for the permissible rate of run-off of the transition curve.

Near the bottom of page 174 begins the report on The Relation of Transition Curves to speed and superelevation. Attention is called to the fact that the whole matter of degree of curve, superelevation, speed, tangent offset, and length of transition curve is covered inflexibly and rather simply by five formulas. The five formulas are given beginning at the bottom of page 174 and continued at the top of page 178. The algebraic development of the formulas is given, and five tables, based on those formulas, are presented. Table 1 gives the elevation of outer rail for permissible speeds. The elevation is given in inches for different speeds up to 100 miles per hour, and elevations up to 7 in.

(He then reviewed the tables.)

Mr. Selby: It is a convenient and fortunate fact that the offset of the transition curve is constant for the elevation and is independent of the degree of curve so long as the speeds and lengths of transition curve given in Tables 2 and 3 are adhered to.

In the historical portion of this report, it appears that in the early days of the development of transition curves a great deal of attention was paid to the particular geometrical form of the curve itself and to the man's name that happened to be associated with the curve, and little attention was paid to the underlying principles fixing the length and offset.

The formulas submitted by the subcommittee, Formulas 4 and 5, are based on the so-called Froude formula which is an approximation of the cubic parabola. The simplicity brought about by that approximation seems to justify the use of the formula for practical work. A fortunate opportunity was presented a few days ago for a comparison of the elevations, speeds and characteristics of the transition curve itself, as given in this subcommittee report, with tables computed by the more precise and complicated formulas of the Committee on Track which appear in the Manual.

In the matter of permissible speeds, the more complicated formula, which involve the tangent of an angle whose sine is given, was compared with Table 1. This table gives the speeds to the nearest mile per hour. Of the 174 comparable items in the two tables, 90 are identical; 77 differ by one mile plus; two by one mile minus, and only five of 174 differ as much as two miles in speeds running up, of course, to high figures. It would appear that that comparison is sufficient justification for the use of the simple formula because those differences are insignificant.

A comparison between similar tables giving the lengths and offsets of the transition curves shows that for curves from 1 deg. to 7 deg. inclusive, of 161 items that were compared, 136 are identical, and 25 differ by 0.01 ft. These are main offsets of the transition curve. Of course, 0.01 ft. is negligible.

The comparison of curves of 8, 9, 10 and 11 deg., not many of which you will find in high-speed territory, shows small differences. Of 60 items compared, only 12 differ by more than 0.02 ft., 7 by 0.03, 2 by 0.04, 2 by 0.05, and one by 0.06 ft. Those exceeding 0.02 ft. were based on offsets amounting to from 5 to 8 ft., so that those differences, again, are insignificant.

I think a pretty good case has been made for the simple formulas in this report. The comparisons I have just described are between a formula that involves sine ½ delta, sine ⅓ delta, cosine ½ delta, and the simple formula that involves only a constant multiplied by the expression L^2D.

I should like to point out that the tables given here are more voluminous than would be needed for working tables by any one railroad. They cover a wider scope as to degrees of curvature and more refinements as to elevations and probably more decimal places in the offsets and ordinates than would be used in actual working conditions.

The purpose, of course, is to make available tables for all the railroads in the Association, tables which are extensive enough to be cut down and used as a basis for working tables by each individual road. The formulas and tables are submitted with the hope that they will bring out discussion, and that next year the committee may be in position to submit for the Manual some more compact tables for actual use.

Vice-President Hastings: Gentlemen, you have heard this portion of the report. The committee asks for discussion.

Mr. Burton: On page 178, near the top, mention is made of a change in the formula for superelevation in which the dimension, gage of track, 56½ in. is increased 0.6 in. to make it 57.11 in. I am inclined to agree with Mr. Selby that the change is minor, but there is some question in my mind as to whether it is desirable to make such a change. First, it is questionable whether overturning occurs about the flange or about the center of the area of contact of the wheel and the rail. We don't know the exact answer, but it is fully as reasonable to use 60 in., the center-to-center distance of the contact areas, as it is to use 57.11 in. As I understand it, there is nothing at all sacred about the 57.11 excepting that it happens to be the reciprocal of 1,500. The change is so slight, and as the 56½ in. is already in the Manual as approved recommended practice, it seems to me very confusing to add a complication to something that is so all-important as safety on curves.

There is another point that is of considerably greater importance. On page 174, at the bottom of the middle section, it says: "Spiral lengths on the basis of running out the elevation at a rate of 1¼ in. per sec. make comfortable riding for high speed traffic." I don't take any exception to that statement at all. I think it is probably true. But that 1¼ in. is taken from the Track Committee's section of the Manual, and, as far as I have been able to find out (and I have made some inquiry during the last year) there is no particular support for it. If there is any support, it is not divulged in any of the reports. The Track committee says that 1¼ in. per sec. is desirable but that, where you cannot have spirals that long, you may use up to 2.2 in. per sec. The 2.2 is almost double the 1¼. With ordinary speeds, this matter was not particularly important, but this factor of 1¼ in. directly affects the length of spiral, as is shown, for instance, in Table 3. Whatever you choose for this factor directly affects the spiral length. The introduction of longer spirals on many existing curves, is usually very expensive. It cannot be done generally. Where it is done, we should be sure that we are not making spirals longer than necessary, on the one hand, but that we are making them long enough for good riding, on the other hand.

I think this factor requires some further investigation. As supporting that thought, we recently have had occasion to obtain some figures on practice in England, where some of the trains, at very high speeds, are reported to ride exceedingly well. I find that the spirals which were used on some of the English roads, are only about half as long as the 1¼ in. factor calls for.

This factor of 1¼ in. is something that should have further investigation. After the correct factor is determined, it is then comparatively simple to prepare tables. It may be that 1¼ in. is insufficiently adequate. It may be that it should be 1 in. Whatever it is, it is very important, and it really is all-controlling in determining the length of spiral, and the length of the spiral is most important in determining the cost of improving an old line for higher speed.

Mr. Selby: The subcommittee has not attempted to go behind the work of Committee 5—Track. We took the 1¼-in. runoff and 3-in. unbalanced elevation as starting points. Personally, I think they are about right, but that is not important. If it should be developed that a greater or less rate of runoff is desirable, then it would be necessary to compute other tables. A rate of one inch per second would greatly simplify the formula; two inches per second would be almost as simple.

As to the gage of the track, the Track Committee's formula is based on 56½ in. It is well known that the gage is not the correct distance to use in this formula. It should be the distance between bearing points of the wheels on the rail. Nobody knows what that is. It is somewhere from 57 to 59 in. The amount, 57.11 in., quoted in the report was not assumed; it merely is the result of using the denominator 1,500, for simplicity. It is agreed that the exact distance is a minor matter, and the simplicity of the formula, using the 1,500 in the denominator, is sufficient to justify it, I think.

Vice-President Hastings: Is there further discussion? If not, this report will be received as information. I am sure the subcommittee will bear in mind the discussion by Mr. Burton.

I will ask Mr. Stout to continue.

Chairman Stout: The committee will be very glad to take into consideration Mr. Burton's criticism, and investigate as much as facilities will permit. I would like to ask Mr. Burton at this time if he knows of any mathematical development to support some figure other than the 1¼ in.

Mr. Burton: I think that is entirely a matter of experiment. I don't think it can be determined mathematically, but I think it is a subject that might well be assigned to the new committee on relation between rolling stock and track or, perhaps, some other committee, but it is something that requires experimental work.

It is my understanding, unofficially (I have never gone into it fully) that some experiments were made on one of the western railroads some years ago, upon which this 1¼ in. was based. It is also my understanding that it is more than is being used by some of the eastern railroads, and it is at variance with some of the practices in Europe, where results, as to riding, are excellent. It is most important in the matter of cost. In many cases you can put in a 400-ft. spiral where you can't put in an 800-ft. one. The cost is way out of proportion to the benefit on existing railroads. If we were building new railroads, it wouldn't be very important, but in changing existing railroads to accommodate higher speeds, it is a most important matter.

Chairman Stout: I assume, Mr. Burton, whatever information you have will be available to the committee.

The next subject is No. 12, Grades and alinement through tunnels. Last year a first progress report on this subject was presented. We now offer a second report of information. It will be presented by Mr. F. N. Nye, chairman of the subcommittee.

Mr. F. N. Nye (New York Central): In carrying forward this assignment, the subcommittee prepared a comprehensive questionnaire designed to elicit information covering not only the problem of tunnel location and the relation of the tunnel to other parts of the railway line, but also certain conditions of operation through tunnels. This questionnaire was addressed to chief engineers of the major railroads of the United States, Canada and Mexico, and embraces all tunnels 1,000 ft. or more in length. The response to this questionnaire to date has been very satisfactory. Well over one hundred replies have been received which are summarized in a brief resumé to be found on page 179. Brought up to date, it may be expressed thus: 65 railroads report no tunnels of 1,000 ft. or greater length; 52 railroads have furnished the requested data covering 421 tunnels in this category. Only four railroads have not yet had an opportunity to reply.

The data have been tabulated and are now being analyzed in order to enable the committee to formulate recommendations as to tunnel location, taking into account certain operating conditions and location characteristics as determined from a study of existing tunnels of this magnitude.

It is recommended that this review of progress be received as information.

Vice-President Hastings: If there is no discussion, it will be so received.

Chairman Stout: Subject No. 13, Economics of railway location as affected by railway electrification. This is a modification and enlargement of previous subjects on electrification of railways, and a first progress report of information on this extended subject is included as Appendix K of the report of the committee.

Professor E. E. King, University of Illinois, chairman of the subcommittee, will present the report on this subject.

Prof. E. E. King (University of Illinois): This year the subcommittee has been engaged in bringing together data on the principal characteristics of steam railroad electrifications in the United States and Canada. These data are shown in Table I, which is a part of this report. They carry on up to the end of 1937 the figures presented by the Railway Electrification committee of the National Electric Light Association in 1933, and the Federal Power Commission in 1936.

Next year we propose to undertake the same program for lines in Mexico and other countries on the western hemisphere and also some in the eastern hemisphere. The committee therefore asks that the assignment be continued for another year, and that this report be received as information.

Vice-President Hastings: You have heard the report, Is there any discussion? If not, this portion of the report will be received as information.

Chairman Stout: No report is offered on Subject No. 5, Methods for determining most economic train length, considering all factors entering into transportation costs, collaborating with Operating Division. Four progress reports of information have been presented since the subject was first assigned in 1931. This year we report progress in study.

Likewise, also, we have no report to present on Subject No. 10, Effects of speeds in excess of 75 miles per hour on the economics of railway location. Two progress reports of information have been presented heretofore.

Before terminating the report of the committee, I think it is becoming, and my sad duty, to refer you to the notice of the death of Mr. H. C. Crowell, a member of this committee, assistant to chief engineer of the Pennsylvania Railroad, New York City.

That completes the report of the committee.

Vice-President Hastings: This committee has given the Association this year a magnificent report, one that has brought very directly to your attention some very vital things in connection with the problems that confront all of those of us engaged in the railway business at this particular time. I want to say that, because we just cannot excuse this committee with the ordinary excuse, with the thanks of the Association.

I want to say in connection with the report that was presented by Mr. Teal, that in these studies of the great expenditures that are being made with public funds for the improvement of waterways and the construction of new waterways or highways, or whatever it may be, there seems to be one great economic fundamental that has been overlooked or else purposely forgotten, and that is, what does it profit us (I am speaking now as a citizen of the United States, not as member of the American Railway Engineering Association) as citizens if we spend vast amounts of tax money or public money in the creation of things that may make transportation cheaper for some if, by the same construction and the same expenditure, we destroy the earning power of the great

arteries of commerce that have through the years built up the country and have, among their operators, thousands of employees whose sole dependence is upon their business, thousands of investors whose sole income may be dependent upon the return which they receive from that investment—what does it profit us, I say, if we, on the one hand, build things for the creation of new ways of transportation or the lessening of the cost at the taxpayers' expense if, on the other hand, we deprive others of a livelihood and the right to earn their own living and, in turn, have to go again to the taxpayers to provide funds for their relief?

Gentlemen, the committee is excused with many thanks of the Association. (Applause)

DISCUSSION ON TIES

(For Report, see pp. 635–640)

(President Morrow presiding)

Chairman John Foley (Pennsylvania): The only item in the report that involves action by the Association is covered by Appendix A, which you will find illustrated on pages 636 and 637 in the form of diagrams submitted to clarify formulas already in the Manual.

It is moved that these three diagrams be added to the Manual.

(The motion was regularly seconded, put to a vote and carried.)

Chairman Foley: Appendix B is the report on Extent of adherence to standard specifications. It contains information developed by the committee during its observations in 1938. It is submitted as information.

President Morrow: It will be so received.

Chairman Foley: Appendix C, covering Tie renewal averages and costs per maintained mile, relates to the information which was published in the June–July Bulletin (1938) and is submitted as information.

President Morrow: It will be received as information.

Chairman Foley: Appendix D is a report on Dimensions of ties, which will be presented by the subcommittee chairman, Mr. Burton.

Mr. W. J. Burton (Missouri Pacific): The committee, acting on its privilege, has elected to report only on the length of crossties this year. The method which has been followed in determining length may be said to be a practical method rather than one involving very much mathematical analysis. It was adopted in preference to other methods because it produced results which were consistent with the known action of ties in track.

Very briefly, the method selected indicates that present crossties are too short to perform the functions of crossties to the best advantage. One of the most important points made is the fact that any increase in length of the tie results in double that increase in the length of that part of the tie which may be tamped without producing centerbound track. This is due to the well-known fact that it is not possible to tamp the center of the track without producing centerbound track, so that if a tie is increased six inches in length, the effective length is increased one foot.

The conclusion of the committee, which is given in the last part of the report, is that an increase in supporting power of the roadway may be obtained by an increase in length of ties at less expense than by other means. It is concluded that, considering the additional tie cost, 8½-ft. ties are a better buy than 8-ft. ties and will give added support out of proportion to the added tie cost.

Because of the lack of time, I will not go into the details of this report. We have considered costs in reaching that recommendation. The added cost for an added length

of 6 in. is minor as compared with the 17-percent increase in support which the 6-in. longer tie affords. As a matter of information, one of the more important western railroads just recently has gone a step further and adopted nine-foot ties as its standard.

President Morrow: Is there any discussion on this feature?

Mr. B. R. Leffler (New York Central): I presume it is in order for a bridge engineer to discuss track problems once in a while.

I am looking at the matter under Distribution of Load, Section (b) page 369. There are about half a dozen paragraphs, and each, I will say, is bristling with problems of analytical mechanics, and I have not had the time to go into the mechanics in detail, but I thought it might be wise to call attention to several features.

To begin with, a piece of track is a structure. That is the reason, as a bridge engineer, I am trying to talk about it. The reactions on the bottom of the tie, together with the load on the rail, must meet certain static conditions. For instance, it says, "Ties laid on solid rock would bend very little." That is true, but neither would the tie carry a uniformly distributed reaction. The reaction would be confined to a very small length on the bottom of the tie directly under the rail.

Now, when the roadbed becomes soft, as I look at it, there would be bending of the tie, but that does not necessarily mean that the tie would be overstressed. It depends on the elasticity of the roadbed. Bending of the tie is not a serious matter, unless the bending has a small radius of curvature. I mention that because it is not the general bending of the tie that determines whether the ties are overstressed.

If you have a tie ten feet long, the assumption is that the stress will be uniformly distributed under each rail, half of the tie, five feet, namely, taking one rail, and the other five feet taking the other rail. That I do not believe, is anywhere near in accordance with actual reaction between the tie and the ballast.

Now, when I say the reaction between the tie and the ballast, I want to make it clear that that is not the same as the pressure on the subgrade. The assumption of a uniform distribution between the tie and the ballast implies that the tie has a hinge at the middle, creating two cantilevers. Even that would not make a uniform distribution on the bottom of the tie, because each cantilever would bend. That would simply mean that the sum of all reactions is directly opposite the wheel load, and about on the axis of the rail.

There is another feature: If the tie is lengthened too much beyond the rail, the bending moment is increased on the tie, directly under or in the neighborhood of the rail. You could conceive of a tie extending beyond the rail, and finally reach a length such that the end of the tie would be carrying no load whatever. In fact it might stick up out of the ballast, due to excessive bending.

Usually, at the point where a rail rests on the tie, the tie is weakened by reason of the damage done by the track spikes, cutting away, in the language of a bridge engineer, a good part of the section modulus of the tie right along the edge of the rail; and, as the tie decays or is frequently respiked, you have a progressive weakness through use. It is quite common to see ties "kicked" up beyond the rail, meaning, of course, that the tie is probably broken on the underside, and is of no further use.

It is impossible to obtain a uniform distribution between the tie and the ballast, if we grant that the tie bends, which we must. To obtain a uniform distribution, or approach it, it may be necessary to increase the depth of a tie that is ten feet long, thus increasing the cost.

I wanted to call attention to a few of these points. I think most of the points I mentioned might be set forth in terms of mathematical formulas, but I haven't attempted to do that.

Mr. Burton: The committee is agreeable to much of what Mr. Leffler said. I think perhaps if he will consider the fact that the tie is not only a beam but a block, and as he has said, much of the reaction is indeterminate. The minute the tie begins to bend, it builds up pressure, and that pressure is not uniform; it varies considerably and indeterminately.

This report takes into consideration the well known fact that we waste the center of the track, as far as support is concerned. We cannot tamp the center of the track without producing centerbound track. The ballast and the tie at the center is therefore wasted. It is an attempt to justify longer ties based on what might be called practical considerations rather than an attempt to determine the proper length by consideration of the bending moments, or something of that kind.

I might say, that a consideration of bending moment, such as has been suggested, indicates a length somewhere around nine feet, but that determination neglects the fact, as pointed out by the Stresses in Track committee, that the ends of the ties are ineffective in developing ballast pressure. As I recall the statement of Dr. Talbot some years ago, from the end of the tie to a point about six inches in from the end, comparatively little ballast pressure is developed, so that there are factors to be considered that are more or less indeterminate.

This result, indicating that ties longer than eight feet are desirable, is consistent with common knowledge. While we understand fully that it is not strictly a mathematical analysis such as a bridge engineer would desire, and we are agreeable to nearly everything Mr. Leffler has said, we believe that this report is in line with best practice.

President Morrow: Any further discussion?

Mr. Leffler: I want to add a remark that I intended to bring out and forgot. I have noticed that in most track discussions there is an assumption to the effect that each rail carries an equal load, but that is not true. The equipment, especially the locomotive, is in a continual state of rolling. The result is that there is a transfer of load from one rail to the other continually. That has been brought out by numerous tests, especially by the Bridge Stress committee of the British railways, and also by Mr. Hunley in the series of tests he made several years ago and reported to the Association. That has been very vividly brought out in recent days by the high speed locomotives which are now being built, in which the attempt is made to reduce the so-called "hammer blow" to a minimum. Motion pictures taken recently show that, in spite of the best locomotive designing, the hammer blows are tremendous, particularly, for the main driver, which may even lift off the rail. When that occurs, the whole axle load must go on the other rail. We know that freight cars vibrate or roll.

Unequal rail loadings are the normal condition of a rail loading; they are not exceptional. I would call the exceptional, one in which it is assumed that locomotive or equipment loading is equally distributed, which only can occur at very slow speed, and only perfectly when the locomotive or equipment stands still.

President Morrow: Any other discussion of this report? Mr. Chairman, is this report presented as information?

Chairman Foley: Information only.

President Morrow: It will be so received.

Chairman Foley: On Subject 3, Substitutes for wood ties, we have made progress in the compilation of statistics, but make no report. On Subject 5, Proper seasoning of oak ties, with special reference to those grown in southern lowlands, progress in the study has been made, but no report is ready. This completes our report.

President Morrow: Mr. Foley, the committee is excused with the thanks of the Association. (Applause)

DISCUSSION ON WOOD BRIDGES AND TRESTLES

(For Report, see pp. 375–399)

(President Morrow presiding.)

Chairman H. M. Church (Chesapeake & Ohio): Your committee desires to report progress on Subject 2, Simplification of grading rules and classification of timber for railway uses. The committee's attention has been called to a proposed revision of the American Lumber Standards, and suggestions for its improvement have been submitted through your secretary to the National Bureau of Standards.

Progress is reported also on Subject 4, Design of wood trestles for heavy loadings; Subject 5, Bearing power of wood piles; Subject 7, Improved design of wood structures to give longer life with lower cost of maintenance; and Subject 10, Specifications and design of fastenings for timber structures, including metal joint connectors.

Subject 1, is Revision of the Manual. In the absence of Mr. Hart, and inasmuch as the changes are of a minor nature, I will present the report myself. We desire to substitute the word "piles" for "piling" at the locations indicated and to correct the tables for the sizes of piles to correspond with what was actually adopted and to conform with the dimensions adopted by the American Society for Testing Materials. There is only one change, namely, 12 in. instead of 13 in.

I move that these changes be made in the Manual.

(The motion was duly seconded, put to a vote and carried.)

Chairman Church: Subject 3, Overhead wood or combination wood and metal highway bridges, will be presented by Mr. Staley.

Mr. G. L. Staley (Missouri-Kansas-Texas): This report on Subject 3 is Appendix B on page 376. The first two paragraphs are explanatory and give some reasons for the recommendation. I want to call attention to the fact that there are no specifications in the Manual for overhead wood highway bridges. For this reason the committee recommends that a reference to specifications for overhead wood highway bridges be included in the Manual, similar to the reference previously adopted regarding specifications for overhead steel highway bridges. The committee, therefore, submits the following for publication in the Manual:

"Specifications for Wood Highway Bridges. It is recommended that the Standard specifications for Highway Bridges of the American Association of State Highway Officials adopted in 1935, or current revisions thereof, be used, subject to the approval of the railway company as to clearances, foundations and construction practices".

I move that this be accepted for printing in the Manual as recommended practice.

(The motion was regularly seconded, put to a vote and carried.)

Chairman Church: Subject 6, Recommended relationships between the energy of hammer and the weight or mass of pile for proper driving. The report will be presented by Mr. Heinlen.

Mr. H. C. Heinlen (Atchison, Topeka & Santa Fe): Appendix C assigned to this subcommittee is divided into two parts, the first of which is the recommended relationship between the energy of hammer and the weight or mass of the pile for proper driving. The original draft as printed here is a resumé of material that appeared in the Proceedings for 1936, and was presented to the convention at that time.

Subsequent to the printing of the report, we had a communication from Mr. Hirschthal inviting attention to a conflict with certain masonry specifications now in the Manual. The committee agrees with him that we should change our recommendation to conform with that specification. Accordingly, we suggest that the first paragraph under the subheading "Steam Hammers" be changed to read as follows:

"For driving concrete piles, the striking part of the hammer should weigh not less than 2,500 pounds and develop energy per blow of 8,750 foot-pounds per cubic yard of concrete contained in the pile to be driven."

This will conform with the statement in the masonry specifications, but is stated in terms of units, rather than showing a specific hammer for the driving of a pile of specified dimensions.

With the foregoing change in the first part of the assignment, this material is offered as information.

President Morrow: Is there any discussion on this report? If not, it will be received as information.

Mr. Heinlen: The second part of Appendix C is the Specifications for driving wood piles, pages 378 to 382, inclusive. I do not have any preliminary statements to make in connection with the subject matter. It is to be presented as information at this time, for study and criticism, pending submission next year for adoption and publication in the Manual.

Mr. C. C. Westfall (Illinois Central): Mr. President, on page 380 there is a paragraph under the heading "Splicing." It says ". . . an approved method of splicing may be used." I object to having the specifications beg the question by using the expression "an approved method." It seems to me that the specification should say what methods may be used. If splicing is to be permitted, then it should tell us the proper manner to splice piles, because our Manual is a guide to the engineer as to how to do his work. I see no difference between sidestepping the splicing of piles any more than to say that an approved steam hammer may be used or an approved jetting system. In those particulars the committee has gone into detail. I think the proper type of splicing or adequate type of splicing should be specified.

Mr. Heinlen: The specification was written to cover a very general case. Obviously, it would be impossible to write a specification to cover the driving of piles under all conditions. There are quite a number of engineers who are of the opinion that splicing should be prohibited. This question was discussed at some length in the committee, and we arrived at the conclusion that perhaps splicing should be permitted under certain circumstances and left to the judgment of the engineer in charge of the work. To specify a kind of splice would take the matter out of the hands of the engineer in charge. We felt it should be included in the plan submitted for a specific job.

Mr. Westfall: It seems to me, if we do not cover it fully and tell how to do it, we had better be silent on it, if the engineer is to dictate in the end, anyway.

Chairman Heinlen: The point is well taken. I would suggest that you give the committee a statement of your opinion, and the question will be given further consideration.

President Morrow: Any further discussion? If not, it will be received as information.

Chairman Church: The subject that has just been presented will be continued in collaboration with the Masonry committee, and we welcome any suggestions to improve the recommendations for next year's work.

On the assignment reported in Appendix D, it is the wish of the Committee on Outline of Work, that we continue collaboration with the AASHO. Accordingly, we would like to offer the brief statement given, as information.

President Morrow: It will be so received.

Chairman Church: Appendix E, Fireproofing wood bridges and trestles, including placing of fire barriers, will be handled by Mr. Johnston.

Mr. J. V. Johnston (Mobile & Ohio): The report of this committee appears on page 382 as Appendix E. This is not a new subject. It was last before this convention in 1922,

when the material now in the Manual was adopted. It has now been reassigned to this committee for further study and, hence, this report.

I shall not read the report but I would like to call your attention to the classification of fire barriers as found on page 385. Fire barriers may be grouped into types of construction for open deck and ballasted deck wood trestles and highway bridges as follows:

1. Earth fill within long trestles.
2. Reinforced concrete piers or concrete pile bents.
3. Fire resistant deck.
4. Facing bents with fire resisting materials.

The application of these methods is shown in sketches that are incorporated in this report. This is a progress report and is offered as information.

President Morrow: Is there any discussion on this report? If not, it will be received as information.

Chairman Church: Subject 11 is Use of tar and asphalt compositions for wearing surfaces on wood floored highway bridges. In the absence of the chairman of this committee, I wish to state that the matter in Appendix F is presented as a general outline of available information.

Section I, for the hot mix, comprises an outline from the specifications of the AASHO. Section II on emulsions, bituminous cut backs, is largely from manufacturers' data. The data on emulsified asphalt are from federal specifications. Section III, Bituminous Concrete—that should be Asphalt Concrete—embraces data obtained from the Bureau of Public Roads and is in use in the various states. Section IV, Tar-Concrete is largely from manufacturers' data. This subject will probably be continued, and it is the hope that the committee may have further data to report at the next convention.

President Morrow: Did I understand you wanted to change the title of III?

Chairman Church: In view of our action in continuing to collaborate, with the amendment we have made, we will allow that subject to stand.

President Morrow: Is there any discussion on this report? If not, it will be received as information. I want to commend the committee for its very excellent work this year, and it is excused with the thanks of the Association. (Applause)

DISCUSSION ON COMPLETE ROADWAY AND TRACK STRUCTURE

(For Report, see pp. 627–633)

(President Morrow presiding)

Chairman J. E. Armstrong (Canadian Pacific): Your committee has struggled with its present assignments for several years, and is presenting a progress report this year, for the first time. Your committee has gone just about as far as it can go by itself. The assignments are highly controversial, and it feels that at this time it must have criticisms and suggestions to enable it to proceed with the work. I am not here to defend the report, but to get you to tell us where it is wrong and how it can be improved.

With your permission, I propose to read Appendix A, because some of you may have not read it, and I don't believe you will be in position to discuss it, unless you know what it says.

(Chairman Armstrong read the report found under Appendix A, pages 627–8.)

Chairman Armstrong: This Tentative Classification of Railway Main Tracks is offered as a progress report for discussion, criticisms and suggestions, with the recommendation that this subject be reassigned for further consideration in the light of such discussion, criticisms and suggestions.

Mr. J. C. Irwin (Boston & Albany): I know that Mr. Armstrong and the committee want constructive criticism. I wish first to commend the progress the committee has made to the present time. It is a very difficult subject to get into; practically a new field. I know that for the first two or three years the subject was assigned, it required a great deal of study to see just how it should be tackled. So far as the progress report goes, it seems to me that it is outlined on a very reasonable basis.

Mr. W. J. Burton (Missouri Pacific): Just to make certain, I would like to ask if the tonnages shown are intended to be gross, including equipment, or are they net tons? Ordinarily statistics are kept of net tons but not of gross tons. Of course, I think it should be gross tons, but I want to make sure that gross tons were what the committee had in mind.

Chairman Armstrong: I would like to make very sure that my reply is understood by Mr. Burton. We mean the grand total of 2,000-lb. tons passing over the rail, whether it be net contents, cars or locomotives. The entire tonnage moving over the rail is what is intended.

President Morrow: Do you think it would be well to include the word "gross"?

Chairman Armstrong: I don't think so, because gross tons sometimes mean 2,240-lb. tons.

Mr. F. L. C. Bond (Canadian National): The report says "including locomotives". That shows what the intention is.

Mr. G. L. Sitton (Southern): I realize the difficulty in getting up a set of specifications like this. But it is not quite clear to me how you would classify a line, for instance, which has passenger trains that are normally operated at average speeds of 60 miles or more per hour between stops (which would put the line in Class A), which has freight trains which are normally operated at average speeds of more than 25 and less than 40 miles per hour (which would put it in Class B), and which has a total tonnage of less than 5,000,000 gross tons per annum (which would put it in Class C). Is it the intention of the committee to put a line like that in Class A, give it the highest ranking?

Chairman Armstrong: If a line carries any one of the three specifications of the Class A line, it is a Class A line under this definition.

Mr. Neubert (New York Central): I don't recall whether Mr. Armstrong brought it out or not, but you must bear in mind that this committee does not originate or recommend the adoption of any standards, plans or specifications. This committee takes what you have in your pantry, and tries to make a meal out of it. It is my idea that the job of this committee is to offer several classes of construction from which the railway executive may select one that best meets the service requirements of his property.

This may not be in accord with what you or Mr. Armstrong or the other members of the committee have in mind, but I will put my idea this way: Take, for example, Groups 1 or 2. You may select 131-lb. rail, stone ballast, heavy tie plates and so forth, or possibly a combination of or intermediate between Groups 1 and 2, depending on the traffic, the physical requirements, and your knowledge of the property. Or, you may find that 112-lb. rail with stone ballast will meet the requirements. Or again, on account of the geographical location and the source of supply of materials, you could take the 131-lb. rail and substitute a ligher ballast, such as gravel, and so forth.

I think those are some of the things that would be helpful. What Mr. Armstrong and the committee ask is that you comment on or criticize this report.

Chairman Armstrong: These classifications that are now being presented as tentative, we hope will be in shape for inclusion in the Manual perhaps next year. In so far as you do not criticize them now, please do not come forward next year and tell us we are all wrong if we put them up exactly as they are now.

President Morrow: If there are no further comments, we will proceed with the rest of the report.

Chairman Armstrong: That carries us on to Appendix B. As that is in very much the same category as Appendix A and is rather short, with your permission I would like to read it.

(Chairman Armstrong read the report found under Appendix B, pages 628–9).

President Morrow: Do we have any comments on this report?

Chairman Armstrong: Perhaps, in order to start discussion, I may say that the tentative schedule which appears on pages 630 to 632, inclusive, is, in some respects, an index to the present Manual material. The committee has distributed this material among Class A, Class B and Class C tracks in accordance with those classifications as developed in Appendix A.

Your committee at the present time cannot see that this schedule can be developed into Manual material. It will change from time to time as AREA Recommended Practice is revised. It will change as some of the gaps now existing in AREA Recommended Practice are filled. We will appreciate a discussion of this, however, with a view to bringing it into the best possible shape.

Mr. Burton: I would like to ask if the element of cost was given any consideration, or was this prepared without regard to specific cost? I have in mind, particularly, the weight of rail. I think it is pretty well known that the labor cost, including all of the follow-up work which accompanies a relaying program is pretty much independent of the weight of rail. You have to spend about so much for labor, regardless of whether you renew with 112-lb. or 131-lb. rail. If this is a fact, then, all that is required to justify 131-lb. as against 112-lb. rail, is the interest on the cost of the added metal. I would like to know whether the committee has gone into such matters in making up this table.

Chairman Armstrong: Up to the present time, Mr. Burton, this committee has not considered economy. We have attempted to set up something to shoot at and we have tried to protect ourselves in the introductory wording. I don't believe that anything absolute can be set up along the line of this tentative schedule.

Rail of a certain weight, which may be economical under certain conditions and fall properly within, we will say, Class B, may be quite uneconomical under other conditions which are only slightly different from those set up for Class B. I don't think we can tie ourselves down absolutely.

Mr. Burton: Along that same line, there is a question in connection with the sizes of crossties. Larger railroads, or those having considerable variation in conditions, or in other words, having roads of Classes A, B, and C, will naturally take all sizes as a matter of economics in the production of crossties. If you take only the larger sizes, in the long run, you must pay for the smaller sizes, too. In other words, you must take the run of the forest.

When you get into questions of this kind, it seems almost hopeless to attempt to set up a standard composition of track because there are elements concerned with the cost of producing materials which outweigh any refinements such as are suggested here.

Chairman Armstrong: I think Mr. Burton has very well substantiated the position taken by the committee.

President Morrow: Are there further comments? The committee is very desirous of getting constructive criticism on this subject.

Chairman Armstrong: Perhaps I can put it this way: Is it better to present this information in the form of a schedule, as we have done here, or would it be more desirable to present it in the form of plans? The committe has adopted the schedule method because there are so many different recommended practices, that, frankly, I

haven't figured out how many plans it would take to set up the various possibilities, but I suppose that could be done.

President Morrow: If there are no further comments, we will receive this report as information.

Chairman Armstrong: I regret that the matter seems to be thrown back into the lap of the committee without very much assistance so far. May I hope that we will have written discussions and suggestions in connection with the matter because, seriously, we need it.

That completes the report of this committee.

President Morrow: The committee is dismissed with the thanks of the Association.

DISCUSSION ON IRON AND STEEL STRUCTURES

(For Report, see pp. 363–371)

(Vice-President Fanning presiding)

Chairman R. A. Van Ness (Atchison, Topeka & Santa Fe): The committee reports progress in study on the following assignments: 2. Specifications for fusion welding and gas cutting for steel structures; 4. Design of expansion joints involving iron and steel structures; 5. Design of tension members and connections in which rivets develop tension; 6. Review specifications for overhead highway bridges of the American Association of State Highway Officials in so far as they relate to steel construction; and 7. Progress in design of steel bridge details.

A report will be presented for your consideration on; 1. Revision of Manual, by the subcommittee chairman, Mr. O. E. Selby.

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis): The material offered is in Appendix A, beginning on page 363. It consists of the revision of three sets of instructions which have been in the Manual for 25 years and which, naturally, have been outgrown somewhat.

The first item offered is: Substitute for "Instructions for the Mill Inspection of Structural Steel" on page 15–115 of the Manual, new instructions as follows:

The new material consists of 15 numbered paragraphs with no subheadings. In general, it follows the form of the material in the Manual, dated 1913, and the revisions are, generally speaking, not of great moment.

(He then read the paragraph numbers consecutively.)

Mr. Selby: I move the substitution of the material just read by paragraph numbers for the corresponding material in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Selby: The next item offered is Instructions for the Inspection of the Fabrication of Steel Bridges, in substitution for material under the same title on pages 15–116, 15–117 and 15–118 of the Manual.

(He read the general headings and the paragraph numbers.)

Mr. Selby: I move the substitution of this material for the corresponding material in the Manual.

(The motion was duly seconded, put to a vote and carried.)

Mr. Selby: The third offering is Instructions for the Inspection of Bridge Erection, in substitution for similar material on pages 15–118 and 15–119 of the Manual.

(He read the captions and paragraph numbers to and including No. 47.)

Mr. Selby: Welded Work; The committee desires to delete the last line of paragraph 48 following the word "Society", so that the article will read:

"48. For instructions for the inspection of welded work refer to Section 9 of the current Specifications for Welded Highway and Railway Bridges of the American Welding Society."

This is followed by paragraphs 49 and 50.

Mr. Chairman, I move the substitution of the material presented for similar material in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Van Ness: Assignment 3 is covered in Appendix B, Different grades of bronzes to be used for various purposes in connection with iron and steel structures. The speaker will present this report in the absence of Mr. Davis.

This subcommittee has collaborated with Committee B–5 of the American Society for Testing Materials on specifications for bronze bearing and expansion plates, to be used in connection with iron and steel structures. The ASTM has adopted such specifications tentatively and Committee 15 recommends that the following reference be authorized for printing in the Manual as an addition to the Specifications for Steel Railway Bridges.

"XVII – BRONZES

"1701. Cast bronze bearing and expansion plates shall conform to the tentative specifications of the American Society for Testing Materials, Designation B22–38T.

"1702. Rolled bronze bearing and expansion plates shall conform to the tentative specifications of the American Society for Testing Materials, Designation B100–38T."

I move the adoption of the matter for publication in the Manual.

(The motion was duly seconded, put to a vote and carried.)

Chairman Van Ness: That completes the report of Committee 15.

Vice-President Fanning: Committee 15 is one of our blue ribbon committees. It is excused with the thanks of the Association. (Applause)

DISCUSSION ON BUILDINGS

(For Report, see pp. 187–218)

Chairman O. G. Wilbur (Baltimore & Ohio): The committee's assignments for the year included nine subjects. Reports on five of these subjects will be presented. No report is offered this year on the other four, except the general statement that progress has been made on each of these subject assignments.

Subject No. 1, Revision of Manual, in the absence of Mr. G. A. Belden, chairman of this subcommittee, will be presented by Mr. Laffoley, vice-chairman of Committee 6.

Mr. L. H. Laffoley (Canadian Pacific): Appendix A, Revision of Manual, will be found on pages 187 to 198. I might point out here that due to rapid changes in building conditions and building materials, and to the fact that the specifications for buildings appearing in the Manual are preceded, in most cases, by a date, the year in which the particular specification was written, although the specification may be up to date, it is sometimes misleading to people who are not familiar with the text. For that reason, we are making a complete revision of all the specifications on material, changing them where conditions call for a change. Because of the amount of material to be presented, I will merely read the captions in which changes are being made, pausing after each caption for any comment.

(Mr. Laffoley read the section headings, concluding with "Doors" on page 192.)

Mr. Laffoley: It has come to our attention that this particular paragraph requires a slight correction to make sense. The sentence beginning "Stiles and rails shall be mortised * * *" should be corrected to read, "Stiles and rails shall be mortised and tenoned and pinned or doweled".

Mr. W. A. Radspinner (Chesapeake & Ohio): Wood shingles are not permitted in a great many communities and the National Building Code recommends against the use of the wood shingle. Really, the communities in which wood shingles were permitted have been almost wiped out. I don't see why the AREA should go on record as recommending wood shingles.

President Morrow: I understand that this is not a recommendation that shingles be used, but it is simply a specification for shingles, if and when they may be used. Is that correct?

Mr. Laffoley: That is correct. We cannot either recommend or prohibit the use of any material but if, on a certain job, a certain material is called for, then we do attempt to guide in the selection and use of this material.

Mr. Radspinner: Why can't you make a notation such as you do in the other portions of your book referring to the code prohibiting shingles and say "where it is permitted"? In the other places you refer to the regulations of the National Electrical Code by reference. Why can't you refer to the National Building Code? It is a part of the National Board of Fire Underwriters regulations.

Mr. F. R. Judd (Illinois Central): I would like to answer that in this way: That a specification is included because the Committee on Wood Bridges and Trestles has a specification on wooden shingles which is in the Manual, and we have followed along that line. At one time the Buildings committee took a stand against the wooden shingle, but when the specification was printed in the Manual by the Committee on Wood Bridges and Trestles, we went along and provided this paragraph which coincides with it.

President Morrow: Does that meet your point?

Mr. Radspinner: If you do it in one place, why omit it in another?

President Morrow: There are places, aren't there, in the United States where they want to use wood shingles?

Mr. Radspinner: In other parts of these specifications you have, "approved by the National Board of Fire Underwriters" and shingles are certainly not approved by them.

(Mr. Laffoley then read the section headings under "Painting and Glazing", also the headings of the sections under "Electric Light Wiring" which embraced changes, down to "Fuses".)

Mr. Radspinner: It is recommended in this paragraph that screw plug cutouts be used, and that they provide circuit breakers. The real hazard is not in the box, it is at the outlet where they put pennies behind these screw plugs, and use other methods to bridge the fuse. Electrical organizations are now recommending early adoption, in the National Electrical Code, of a mandatory rule against the use of a screw plug except of the tamper-proof type. This also eliminates the possibility of using the cartridge fuse. In large buildings where these outlet switches or outlet boxes cover a great area, you don't find the little screw plugs, you find the cartridge fuse. This is not modern practice; this is obsolete stuff.

President Morrow: What has the committee to say about that?

Mr. Laffoley: I think that is covered in the first paragraph: "All electrical work shall be done in accordance with the National Electrical Code, except where local laws or regulations conflict, in which case such laws shall govern". As long as the National Electrical Code permits installations as indicated, I think we are covered. If the National Electrical Code sees fit to prohibit the use of any of these particular types of installations that we call for here, the specification then is changed automatically.

Mr. Radspinner: That is not good practice.

Mr. Laffoley: The last two sections cover Wiring Systems and Outside Wiring. It is recommended that these revisions be made in the Manual, and I so move.

(The motion was duly seconded, put to a vote and carried.)

Chairman Wilbur: Subject No. 4, Maintenance of wearing surfaces of platforms and floors in railway buildings, will be presented by Mr. H. M. Church, chairman of the subcommittee.

Mr. H. M. Church (Chesapeake & Ohio): Appendix B is shown on page 196. This report covers general types of maintenance applicable to platforms and floors, varying as to methods for light and heavy duty service. It is supplemental to Appendix E, on which we are also reporting. The materials are shown under the following headings:

(He read the various headings.)

Mr. Church: Under Section 2, Wood, paragraph 2, line 3, it is desired to change "½ in." to "⅜ in.", as the suggested minimum thickness of steel trucking lanes. That is in order to make it consistent with Appendix E.

This report is offered as information.

President Morrow: Any discussion on this report? If not, it will be received as information.

Chairman Wilbur: Subject No. 5, Air-conditioning of buildings, is divided into two sections. Mr. A. C. Irwin will present Section 1.

Mr. A. C. Irwin (Chicago, Ill.): The first section covers air-conditioning in buildings. Several starts were made to prepare a comprehensive report on the subject, but it was finally decided that all we could do would be to state some general principles that ought to govern the consideration of air-conditioning. This report is intended, therefore, only to cover some of the things that ought to be watched and looked after by responsible officers, when air-conditioning is being considered. This completes the report, Mr. Chairman, and it is offered for information only.

President Morrow: Any discussion on this report? If not, it will be received as information.

Chairman Wilbur: The second section of this subject will be presented by Mr. F. R. Judd.

Mr. Judd: The second section, Air-conditioning of Buildings, for storage and treatment of fruit and produce, is designated as (b) and comprises information on the storage and treatment of fruit and produce, and includes two phases in the marketing of perishable products as follows: (1) Storage, during which time an attempt is made to arrest the natural ripening process of a product, and, (2) The controlled ripening of a product to suit the market demand.

Under these headings, the report discusses in detail the question of temperature ranges, humidity, ventilation, air circulation, and gives an example of the process of storing and ripening of bananas and pears. Following the discussion on these two commodities, a section is devoted to equipment. This deals with the method of insulation and the various types of equipment which should be considered in this class of work. The committee has taken advantage of the information on this subject made public by the U. S. Department of Agriculture, of recommendations of the Oregon-Washington Pear Bureau, the Fruit Dispatch Company, and also of an intimate knowledge gained from the actual design of banana and pear ripening facilities.

The report concludes with an appendix giving the recommendations of various authorities on temperature, humidity and so forth. The commodities comprising fruits, berries, melons, vegetables and flowers are taken from the classified railroad tariffs. While information on all of these commodities is not available at present, they have been listed with the idea of adding information whenever it becomes available. The meats, fish, beverages and dairy products are not divided into various classifications in the tariffs as are the other commodities; therefore the commodities listed under meats,

fish, beverages and dairy products were taken from the various authorities on cold storage, and consequently the data are much more complete.

The appendix shows clearly the lack of information on the subject at the present time with regard to certain of the commodities, especially among fruits and vegetables. It is thought, however, that the developing of air-conditioning as applied to processing will be given more attention, and the subject will be amplified as the producers, shippers and carriers use this method of controlling the ripening and storing of such commodities. On completion of the report, it was submitted to a number of cold storage concerns, horticulturists and the Oregon–Washington Pear Bureau for their comments. All commented favorably upon the report, showing us it is in keeping with present practice.

The storing and handling of commodities along these lines will undoubtedly develop extensively as time goes on, and much additional information will probably be available. Therefore, your committee suggests that the report be accepted as published at this time, as information, with the thought that it is a subject that can be reassigned at a later date.

President Morrow: Is there any discussion?

Mr. Radspinner: This committee was rather solicitous about protecting roofs of houses. I wonder why they don't protect the users of gas ripening for bananas. No reference is made to the ripening of bananas by a method other than the use of ethylene gas. There are about three or four methods to the one of ethylene.

Mr. Judd: To what part of the report do you refer? Will you give me the paragraph and the page number?

Mr. Radspinner: You have picked out banana ripening, on page 202. A common practice in our part of the country is to use the gas stove or the kerosene stove. A lot of people who handle commodities of that kind do not have the complete cold-storage facilities they have in New York City.

Mr. Judd: I hardly think that subject would come under air-conditioning and cold storage, which is the subject here.

Mr. Radspinner: Banana ripening is the subject.

Mr. Judd: No, banana ripening is only a sub-heading under Air-conditioning of buildings for the storage and treatment of fruit and produce. We are only talking about the air-conditioning of buildings. This is the method used under that heading for the ripening of bananas. We are not talking about other methods of ripening or other methods of handling any kind of product except the air-conditioning of buildings for the purpose mentioned here.

Mr. Radspinner: It says under "Equipment": "After the type of structure has been determined, care should be exercised in the mechanical equipment to be selected."

Mr. Judd: That is the equipment required for the air-conditioning and processing, as mentioned in the report.

President Morrow: Mr. Radspinner, you are talking about the subject of ripening fruit in general, as I take it, that is, I mean bananas.

Mr. Radspinner: No. The bad location of one of these ripening rooms has an effect on the insurance which covers the whole group. You can take a group of buildings that are covered by a certain amount of insurance, and if you do anything to increase the hazards in one of them, the whole building may take the same risk. If you put one of these ripening plants in the midst of a group of buildings and do not provide approved protection, you may affect the whole insurance rate.

President Morrow: That does not seem to come under the assignment on which the committee is reporting.

Mr. Judd: As a matter of fact, our report does not cover that at all. We just mention requirements for the ripening process, such as humidification, ventilation, and temperature control. There is no fire hazard involved in the report that is covered here.

Mr. Radspinner: Ethylene gas does not have anything to do with temperature control.

Mr. Judd: Our report does not provide for it, as it is outside the subject.

Mr. Radspinner: It says "Use of Ethylene Gas" on page 203.

Mr. Judd: That is covered by this: "The mixture of ethylene gas and air is neither inflammable nor explosive, except at very much higher concentrations than those recommended for banana ripening."

President Morrow: Is there any further discussion on this report? If not, it will be received as information.

Chairman Wilbur: I am surprised to hear Mr. Radspinner admit that in his section of the country they permit the use of kerosene stoves in these banana ripening rooms.

Subject No. 7, Study of improved wearing surface for platforms, will be presented by Mr. H. M. Church, chairman of this subcommittee.

Mr. Church: This report, which appears on page 211, was given practically in this detail last year, with the expectation that it would be presented for inclusion in the Manual, and with a view of getting comments and suggestions for improving the report. As no suggestions have been received, it is now offered in practically the same general form. I will read the general headings in order to save time. I might point out some of the changes made during the year. We have also been a little more specific in our references to materials, but I will not mention those under the specific paragraphs. The report is divided as follows: (1) General; (2) Wood; (3) Brick; (4) Concrete. I might add that we have added a paragraph on page 213 pertaining to coarse aggregates to resist abrasion. This is taken from the specifications of the Masonry committee which were approved last year. (5) Bituminous; (6) Wood Blocks. Under this paragraph there is a slight revision, including the addition of the words, in the second line "excessive humidity or the building is heated", together with a few other minor changes to bring this more in line with the American Wood-Preservers' Association specification, which is recommended for use. (7) Steel and Iron Plates. This report is complete and is offered for inclusion in the Manual, and I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Wilbur: Subject No. 8, Railroad test laboratory—layout and test equipment, will be presented by Mr. C. M. Angel, chairman of this subcommittee.

Mr. C. M. Angel (Chesapeake & Ohio): The report will be found on pages 214 to 218, inclusive. It covers the proper location of the test laboratory. A suggested laboratory floor plan, based on a building for approximately 7,500 sq. ft. net floor area, is shown on page 215, which is thought to be ample to handle the testing work of 3,000 to 4,000 miles of line. Included in the report is a general description of the building and interior arrangement. On page 217 are listed the recommended machine tools for preparing the specimens for test and a list of the physical laboratory test equipment required. Starting at the bottom of page 217, and on page 218, is given a list of equipment which should be included in the chemical laboratory for general test work. This report is complete and is offered as information.

Mr. Radspinner: I want to thank Mr. Angel for putting fire protection in there. (Laughter)

President Morrow: If there is no further discussion, it will be received as information.

Chairman Wilbur: This concludes the report of Committee 6—Buildings.

President Morrow: Mr. Chairman, this is a very excellent report that the committee has presented this year; it represents a great deal of work. I wish to compliment the committee and excuse it with the thanks of the Association. (Applause)

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